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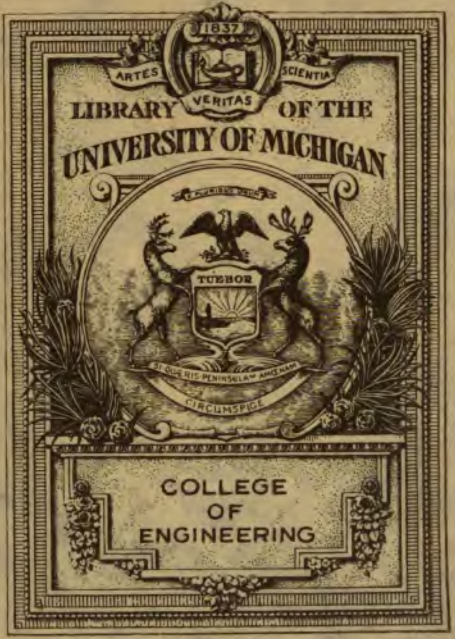

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CONTINUOUS RAILWAY BRAKES

CONTINUOUS RAILWAY BRAKES

A PRACTICAL TREATISE

ON THE SEVERAL SYSTEMS IN USE IN THE UNITED KINGDOM
THEIR CONSTRUCTION AND PERFORMANCE

BY MICHAEL REYNOLDS
MEMBER OF THE SOCIETY OF ENGINEERS
AUTHOR OF "LOCOMOTIVE ENGINE DRIVING," "STATIONARY ENGINE DRIVING,"
"ENGINE DRIVING LIFE," ETC. ETC.

With Copious Illustrations and Numerous Tables

LONDON
CROSBY LOCKWOOD AND CO
7, STATIONERS' HALL COURT, LUDGATE HILL
1882

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LONDON:
PRINTED BY J. S. VIRTUE AND CO., LIMITED,
CITY ROAD.

Engin.
Arth.
10-2-28
17763

Reclaimed 2-27-42 MJL

PREFACE.

Continuous brakes fill an important part in the conduct and working of railway trains, and I have endeavoured to contribute my quota of experience in brakes, for the diffusion of knowledge and the prevention of accidents. The occurrence of frightful accidents has received a check of late by the introduction of continuous brakes. The use of the block-system and interlocking points cannot prevent exceptional cases of accidents: the derailment of a train, for instance, by the failure of the permanent way. Móre accidents have happened by defective permanent way than by any other cause. Such accidents may be repeated, and it is therefore imperative that we should be prepared for exceptional cases. A train may be fitted with a continuous brake, which, whilst the train is on the metals, is all right, but, when the train is off the rails, is all wrong.

I have endeavoured to explain from my experience what a continuous brake should be capable of doing, and when it is found most useful. I have given cases to show that a continuous brake in the hands of the driver would, in all probability, have saved the lives of passengers who were killed. With such evidence before us, every accident which takes place in the future with fatal results will, no doubt, be subjected to rigorous investigation.

It would be difficult even now to predict how it would fare with a railway company who were unfortunate enough to have a fatal accident on their line, with a train not fitted with a continuous brake, seeing that there are many kinds of continuous brakes in use. Even the worst continuous brake is a marvel of improvement on the old system of separate and independent brakes under the control of the driver and the guards, worked by the primitive mode of turning handles.

I have endeavoured to illustrate continuous brakes for the ordinary reader, at the same time adhering closely to technical details of construction for the professional reader. I trust that sufficient will have been said on each particular brake to convey at once a popular idea of the principle and the relative connections of the various parts, and a fairly accurate view of the mode of working.

I have aimed at presenting practical facts, and have avoided theoretical rules and formulas. In a word, I have found the facts in my railway experience, and here they are for the benefit of all.

MICHAEL REYNOLDS.

March 1, 1882.

NOTE.

I recommend for serious study by the railway world this work of Mr. Reynolds', on the subject of Continuous Brakes, the text of which I have had much pleasure in revising. He has brought together accounts of the leading systems of Continuous Brakes which have been tested by practical working in this country, and has, in addition, given the benefit of his judicious criticism, tempered by experience, which must prove valuable to all who desire to understand the subject.

D. K. CLARK.

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CONTINUOUS RAILWAY BRAKES.

CHAPTER I.

INTRODUCTION.

One of the most important questions of the present day is, What can be done to prevent fatal accidents?

Engineers, from Stephenson downwards, have attempted, in one form or other, its solution. Time and talent and money are needed to make a locomotive go. But the engine having been made to go, it became as hard a problem how to stop it. Before the stage-coaches had left the road, locomotives had commenced their little collisions. There was a great outcry against railways, and this was due entirely to the fact that, after the engine was started and had attained its maximum speed, it could not be stopped within a reasonable time and distance, and therefore intending travellers were afraid to risk their necks. No one can look upon one of our modern locomotives going at the rate of 60 miles an hour without, in his heart, breathing a prayer for the safety of the living freight behind it.

The railway companies have seen and fairly appreciated the risks.

Improvements have been made in signals, in order to keep the trains apart. Every accident which has happened has been investigated with great care, and has been traced to the indirect cause. The direct cause has been, in many instances, entirely ignored, or has not been considered of sufficient importance to warrant its being dragged to the front and saddled with its share of the responsibility. If one train collided with another, being within the signals, the remedy was to fine or discharge the driver for not obeying the signal. If the driver succeeded in proving that the signal was in an improper position, or was an improper working signal, he would get off with a fine; if he did not, he would be discharged. He might be energetic, or idle; he might be trustworthy, or the reverse; he might be skilful, or incompetent; he might act intelligently, or ignorantly. No allowance was made for running past a danger signal. This rule was held sufficient to ensure exact obedience; and it no doubt was possessed of efficacy in maintaining freedom from accidents. But it was simply a striking example of the difficulty of detecting the nature of the changes which must of necessity take place where prevision is required, as regards the safe working of a complex system.

From the very first, one of the exigencies for safe travelling must have struck many people. If the driver was supposed to be gifted with prevision or forecast, and was always to shut off steam in time, it was only reasonable to expect that the efficient heads of his company would likewise possess foresight, and would have placed all the brake-power in the hands of the individual who they knew could, in almost all instances, see the danger in front of him, or would be the first to find out that he had inadvertently kept the steam on too long. Even now he has, in some instances, no control over the train unless he works at parliamentary speed. Should he be running at a speed of 60 miles an hour and see an obstruction in front of him a mile off, he may be powerless to stop at it. It will form one of the most remarkable pages in the history of railways that the whole, or nearly the whole, of the improvements which have been made are the fruit of human sacrifices, and not the result of man's longsightedness.

Who would like to go back to the days when there were no signals; when it was not unusual for a driver to oversleep himself, and the train was on that account delayed; when some of the carriages were open at the top; when the driver could stop anywhere and blow up the fire for more steam? The changes which have swept these things away have proved of mutual benefit to the public and the companies. Here we come upon the law of reciprocal advantage, one of the glorious principles which, if followed, must lead to prosperity.

The company which does, to use a common expression, what it likes with its own; which does as it pleases with its capital, will sooner or later find itself face to face with an antagonistic inexorable law of nature, which has for its aim the material welfare of all, and is powerfully at work for the progress of all, in comfort, in health, in life.

The world at large knows that a paper war has been going on between the Board of Trade and the railway companies respecting brake-power relating to passenger trains. For many years, it has been well known that drivers have run into danger with no power to help themselves excepting by applying six wooden brake-blocks to the six tender-wheels of the engine. To describe what this inefficient brake-power has led to, would be to record some heart-rending scenes, giving rise to a doubt as to whether the brake-power could not be augmented. In many instances, it was clearly shown that danger was observed a mile ahead, but all the driver could do to avoid a collision was in vain. Collisions were palpably the result of insufficient brake-power, and the Government Inspector brought the matter before the Board of Trade. This was done in 1858, and what followed was a step forward, though it was insufficient to meet every case. What was done was this: the companies added more brake-vans to their trains; and in order to economise and keep down the length and weight of the train, they constructed what is commonly called a composite brake-carriage; having a small compartment for the guard, and the remaining compartments for third-class passengers. Still, accidents happened, and it was not an uncommon thing for drivers to get all the blame, the railway officials over him presuming (and it could only be presumption, as they were not on the engine) that he relied too much on this additional brake-power, thereby rendering it of little or no value. But, with an increase of brake-power, there was still the necessity for arousing the guards to act; and, if the train was loaded with luggage, they had, in many instances, to go from one end of the van to the other in order to apply the brake; having been, at the time when the driver saw the obstruction in front of him, and gave the signal, engaged in sorting letters and parcels. Much time was thus lost, just when it was required; and, although the means were at hand, if promptly used, of stopping the train, yet, for want of concentrated action on the part of those in charge of the train, many valuable lives and much property were destroyed.

Public opinion was brought to bear upon these lamentable failures of duty towards confiding travellers. Failing to place a brake under the control of the driver, by which he could have full power over the train, many companies were nevertheless induced to move the distant signals farther from the stations, so that the driver should have a greater distance in which to pull up.

The time in which a train could be pulled up was not considered of any great importance. It was the belief of many officials at one time that, to put the whole of the brake-power into the driver's hands was simply exposing the whole of the stock to be smashed to atoms in the course of a very little time. It was said that the driver would run past stations and junctions, and drive to Jericho, or somewhere worse. It was looked upon as madness; the guards made all sorts of objections; and out came the block-system rather than that all control should be given to the man at the head of the train. He was considered a man of a doubtful sort to have control. By such a course, power was taken from the department represented by the guard, and transferred to the one which did all the work and wore no buttons.

But, notwithstanding the introduction of the block-system, the tide of reform which had already set in in some quarters was destined to cover a greater area than ever. It became evident that something more was demanded than signals to arrest a *derailed* train in order to prevent its dashing into a stone bridge or into a chasm. The companies could no longer resist the fact that it was an awful and dreadfully wicked thing to hurl their passengers into eternity through want of stopping power, especially as the power was in the market for them, to be bought if they chose.

Under the gentle stimulus of the Board of Trade, backed by the power of the press and of public opinion, the companies were invited to make a show of brakes at Newark, in 1875, for stopping trains within a reasonably short distance. This was the desideratum, in case of a sudden accident, such as a waggon-axle breaking, or a pássenger train being placed in immediate danger by a goods train crossing the line, as at Carlisle and other places, or a train being thrown off the track by a broken rail.

The experiments made at Newark, hereafter described, were of an interesting character. The interest excited was not by any means confined to engineers, as it affected the future working of railway trains, and the safety of the travelling public, who were as desirous as the railway officials to possess the best means for diminishing the number of accidents. These means have chiefly reference to the employment of powerful brakes called continuous, by which brake-blocks can be applied to all the wheels of a train, entirely under the control of the driver and guard, powerful and rapid in action, and at the same time distributing the power to all the wheels, and diminishing the wear to which rolling-stock and permanent way are subjected by stopping trains.

Circumstances may arise which would necessitate immediate action on the part of the guard, independently of the driver, such as the breaking of an axle, a carriage leaving the rails, a signal from a passenger, or a train on fire. Thus, the whole of the brake-power is occasionally required by the guard. Again, the engine might break away and leave the tender and the carriages behind to follow it, perhaps, down a steep incline, with no one to stop it but the guard. Should it be dark, he might not be aware of what had taken place at the front of his train. Therefore, the whole of his brake-power should be self-acting and capable of bringing a train to rest. A train may part asunder in the middle at high speed when running over the back of a bank, or running down a descending gradient. In the second case, the rear portion may overtake the front portion. Accidents of this kind, although rare, are very violent in their character, as there is a repetition of collision. Therefore, in these cases, also, the brake should be automatic or self-acting. A train may start from a terminus with the brake in good working order, to all outward appearance; and, when under steam at 60 miles an hour, a cow may be seen on the road, and all at once the driver or the guard—whichever first may see the cow—finds that the brake is out of order. He finds, also, that the train started with it out of order; and therefore the brake must be its own tell-tale before starting. It might tell its tale by arranging that whenever or wherever a train or a carriage is separated from the engine the brake shall be found "on." This will necessitate the driver taking it "off" before starting; and consequently he will know before he moves his engine whether the brake is in complete order, and ready to act when required.

There is another point. The efficiency of the brake-power varies with the number of wheels furnished with blocks; for if two or three carriages not fitted with blocks are coupled on, either in the middle or at the end of a continuous-brake train, the distance run after the application of the brake will be augmented in consequence. Such a train is not, then, in the literal sense of the expression, fitted with a continuous brake.

We have briefly explained why the question of brake-power has in recent years become a topic of universal discussion, and we have traced its being to the law of progress—a law which cannot be ignored by any body of men who profess to be the servants of the public. They have to swim with the tide which is bearing the nation onwards, covering and destroying old theories and revealing new ideas.

CHAPTER II.

EARLY BRAKES ON RAILWAY TRAINS.

It would indeed be an impossible task to say with whom the honour rests of having invented the first brake. Like all great inventions, it is claimed by many, for, when a want is felt, the minds of many men are directed towards supplying such want. Let one man die or give up the pursuit, and another is raised to take his place, or perhaps is doing the same thing elsewhere.

The custom is to sneer at all early attempts, which in their crude form may be very insignificant-looking. It is difficult to apportion the due share of merit which belongs to mechanical inventors who are accustomed to work in some instances upon each other's hints and suggestions, as well as by their own experience. "There is nothing," says Hawshaw, "really worth having that man has obtained, that has not been the result of a combined and gradual process of investigation." The first idea, born within some unknown brain, passes into other brains, and at last comes forth complete.

One starts an idea, another develops it, and so on progressively, until at last it is elaborated and worked out in practice; but the first, not less than the last, is entitled to his share in the merit of the invention.

Sometimes a great original mind strikes upon some new vein of hidden power; but more frequently inventions are not entirely new, but are modifications of contrivances previously known. Inventions may come before their time. The advanced mind projects some idea which cannot be executed until the next generation, either through the want of the requisite means, or because there is no demand for that particular kind of invention. Many of the greatest inventors have lived neglected and died penniless, and in their lifetime they secured nothing, excepting dry bread, envy, malice, and detraction. It is worthy of notice that, of those whose names are rescued from oblivion and recorded in the immortal page of the world's history, most walked forth into the world from places only a shade better than hovels, clad in corduroy, and grimed with soot, with a strong smell of ill-fare about them. The names of many are lost. Who invented the brake? As a matter of history, it is necessary to mention that brakes were employed before the railways were worked by engines. When horse-power was employed to draw waggons from the coalpits to the quays, the maximum load for each horse was three tons; and where any declivity more than usually steep, termed a "run," occurred, the horse was hooked off and the waggons were retarded by a hand-lever. For a long period of time, no attempts were made to counteract the rapid descent of the waggons or carriages, as they were then (1796) called, except by means of hand-levers and ropes. The ropes were used on each side of the front waggon by the waggoners, being extended across the front; but the men often failed to stop them, and the result was the occurrence of many sad accidents. Incredible as it may appear, work was suspended and the trains did not run when the rails were wet and slippery; so that it was all sunshine work, barring accidents. Sometimes horses were required to check the velocity of the waggons, but the momentum overpowering them, they were almost sure to fall, and horse and man were frequently killed outright, or left maimed for the remainder of their lives, by being dragged down the declivity or incline. To prevent such accidents, and to utilise the periods of time lost by slippery rails, Mr. Le Caan, of Llanelly, in Carmarthenshire, constructed a brake of great simplicity, which, at the time he exhibited it, was attached to a common cart used upon rails. This brake was afterwards applied for checking or stopping carriages under the circumstances already mentioned, and was very successful in its application. It was described before the Society of Arts in 1801, and received the notice which is generally accorded to original inventions.

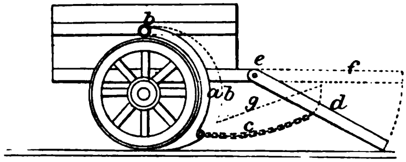


Fig. 1.—Le Caan's Brake.

The brake is illustrated by Fig. 1. *a* represents the brake-block, which, let it be particularly noticed, was of cast-iron, not of wood, pressing against an iron tyre; the block was made a little broader than the tyre of the wheel, so that the wear should be equalised across the whole of the tread, and it covered half the circumference of the wheel. The top of the brake turned upon a pivot, *b*, fixed over the centre of the wheel. The lower part was connected by a strong chain, *c*, to the shaft *d*, which was jointed at *e* to the frame of the cart or waggon. When the horse was upon his legs, the shaft, chain, and brake were in the several positions shown by the dotted lines at *f*, *g*, *b*, the brake being then quite clear of the wheels, as well as the rails. When the horse falls—these are the inventor's words—the shaft takes the inclined position shown at *d*, and the iron brake-block, by its weight, is thrown under the wheel. The rolling motion is changed into a sliding one, and the skidding of the wheel either stops the descent of the carriage or retards its progress sufficiently to prevent the horse being injured or mortally wounded. After reading the description of this brake, one is almost disposed to accept the words of Chaucer as true, that "There is nothing new but what has had time to get old;" or, as another writer puts it, "There is nothing new but what has before been known and forgotten;" or, in the words of Solomon, "The thing that hath been is that which shall be, and there is no new thing under the sun."

After a lapse of half a century, brake-blocks of cast-iron were the other day a kind of wonder, and they engrossed attention as being of modern invention. Be that as it may, we will snatch Le Caan's name from oblivion, for his brake is, or rather was, the father of all others, and he must have possessed the faculty of invention in no ordinary degree. There are many who can seize upon and develop the ideas of others, who are never able to conceive an original idea for themselves.

By a long succession of experiments, this brake of Le Caan has been improved, and, as seen in the present day, there is scarcely a point in it which has not formed the subject of a patent. But to the gifted individual who conceived the idea of regulating the pressure of the block against the face of the wheel by means of a screw, belongs the merit of having achieved no ordinary result, for under *his* system we have the value of its application and the value of the power; and, for some time, nothing will supersede it as a manual retarding force—a hand engine of great power.

But this hand-brake was not applied to the earlier locomotives, nor was it required, for the plain reason that the engineers were putting projecting heads of nails or bolts in the rim of the wheels, and the friction between the road and the wheel was sufficient to overcome the action of gravitation on the inclines, and when, after the lapse of some years, it was found out that smooth wheels had sufficient "bite" on smooth rails, to effect a progressive motion, the power of the engine was absorbed in moving itself and its load. There was in fact no accumulative force in reserve to necessitate the use of a retarding power, and none was used. The resistance to motion was nearly on a par with the force to produce it; and this was the "morkin" that checked the use of locomotives at first about Wylam; and the origin and sole cause of its final success was due to the reduction of what may be termed internal friction in the engines. The cylinders were bored out, their position in relation to the crank was improved, and a deal of dressing was constantly going on; and these ameliorations played so conspicuous a part in the front, at the back, and sides of the machine, that it was often made to spring ahead a few yards when the regulator was open. Instead of an air of unwieldy massiveness, it had the marks of go about it. But the brakes were minus, and it became of essential importance to be able to arrest the progress of an engine. It was a new idea, and in spite of the objections, which were many, the awkward fact that the engine had become too smart in its movements, led to the use of ordinary hand-brakes. There can be no question about the Stephensons having heads like a carpenter's shop; nor of their self-consciousness in all matters affecting their wide-spreading popularity, and so they set to and schemed a brake which was before all others of its class, and it is the origin of the brakes which in the last few years have been doing such good service on engines as train-stoppers—that is, the steam-brake. Mr. Robert Stephenson, under a patent dated 7th October, 1833, "proposed to employ the force of steam upon pistons or plungers in small cylinders; so that, when it is required to stop the train, it is only necessary to turn a small cock, which allows the steam to flow instantaneously through a pipe into the cylinder, and by its pressure on the piston give motion to a system of levers, which cause two brakes or clogs to be forced against the peripheries with great energy, and to arrest the motion of the vehicles very quickly. These clogs, or brakes, and their mode of action, are shown in the side elevation, Fig. 2. *a* is the hollow cylinder into which a plunger is fitted, to act by a lever and an upright rod upon the two brake-blocks, *d*, *d*, which are suspended by pendulous links from a centre pin or bolt fixed to the frame. The brake-blocks are caused to apply to the tyres of the wheels *k* and *m*, by means of links, which are interposed between the two brakes, and which links, when put down into an angle, as shown, leave the brakes free of the wheels; and when, by opening the steam-cock *c*, the steam from the boiler is admitted through the pipe *b* into the hollow cylinder *a*, it raises the plunger therein; and the latter, by its lever and rod, draws up the links towards a straight line, when they force the two brake-blocks apart from each other, against the wheels *k* and *m*, with multiplied force. When the handle of the cock *c* is turned the other way, it allows the steam to escape from the cylinders into the open air." A vast amount of experiment and calculation was expended on this design with no material effect, except to deter others from imitating it. The reason is not far to seek. Stephenson applied the steam-brake on the left side of the engine only, and did not by connections apply it to the

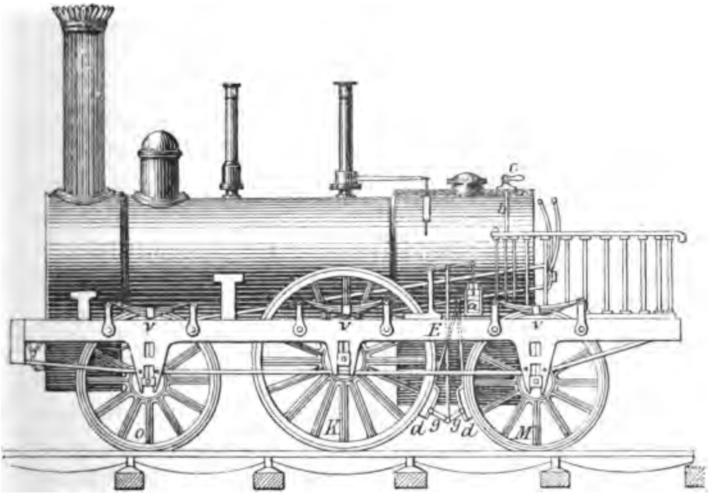


Fig. 2.—Stephenson's Steam-Brake.

wheels of the right side, which omission would obviously cause the engine to make a movement similar to that of a ship when the helm is ported. That is, supposing that the engine could leave the rails and run on the ground with a brake-pressure on the left wheels, she would describe a circle, and therefore, on a straight piece of road, would be liable to leave the rails. Stephenson knew that, on such an arrangement, there would be great lateral pressure of all the flanges against the rails on the brake side, and therefore he removed the flanges from the driving-wheels, or rather did not put flanges on the driving-wheels of the first engine that he fitted with a steam-brake. So the objection was partially overcome. To bring home the impression of one other essential objection, imagine a crank-axle erected on one end and loaded at the other with a fly-wheel making two hundred revolutions a minute, suddenly breaked through a powerful lever at the lower end, and massive as a crank may be, we can easily imagine that a considerable amount of torsion or twisting must take place amongst the fibres of the material before it is brought to rest; and if it were not strained beyond the limits of its strength, it certainly would be injured, and therefore it would not be a matter of surprise if this steam-brake increased the scrap ruck. Again, the "buffing" apparatus resorted to at that period of time was in its childhood, and although, on the Manchester line, it consisted of a series of rods and elliptical springs, it had a wide range of action. In the first place, the buffer-rods extended two feet beyond the framing of the carriage, and, as illustrated by Fig. 3, they were not coupled together. It was thought that, if one carriage had a swinging lateral motion, the others would catch it. The elastic force of the spring was adjusted so that it could take up the resistance of the carriage slowly, and so as almost to be imperceptible to persons sitting within it. The following carriages in the train were, by similar "nursing," brought from a state of rest into motion at a speed of 20 miles per hour. When the steam-brake was put on—as some drivers do put it on—the folks were very unpleasantly jostled together, first ahead and then back; and the concussion was not in any way adapted to induce people to patronise the line.

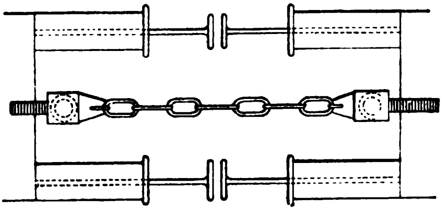


Fig. 3.—Slack Coupling.

Various attempts were made to get over the difficulty, all under letters patent; and it is interesting and amusing to know that close-coupling was the subject of a patent in 1835, until which period the carriages were left apart. Mr. Booth's patent is illustrated by Fig. 4; *a a* is the connecting coupling, consisting of a double-working screw. It is too well known to need to be further described; but it is shown here to illustrate the means which have been at work to produce combined steadiness and smoothness of motion, and so to reduce the number of accidents. The radical action of Stephenson's steam-brake was not regarded as a safe adjunct to railway machinery, and the ingenious Mr. Booth, who was secretary of the Liverpool and Manchester Railway, patented a different contrivance for checking the speed of the engine or stopping it alto-

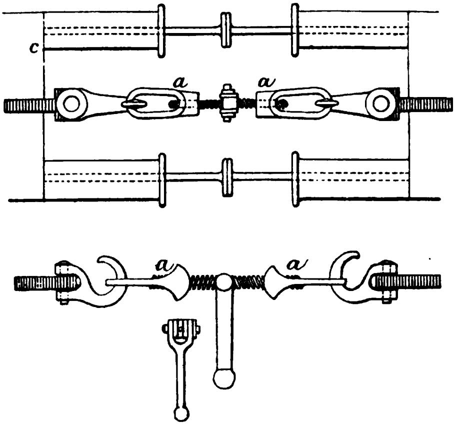


Fig. 4.—Booth's Tight Coupling.

gether in case of an accident. He introduced a throttle-valve into the exhaust-steam pipe, or blast-pipe. From this valve a rod extended to the footplate for the convenience of the driver; and if he had tied a piece of string to it it may have been made convenient for the guard. By moving the valve by means of the rod, the blast-pipe was partially or altogether closed; and the driver when he wished to stop, without shutting off the steam, had only to contract this throttle-valve, or close it, in order to skid the driving-wheel: a result which was caused by the back pressure on the piston. The train could by this means be checked at pleasure, provided that the driver contracted the exhaust-pipe judiciously; but it is a well-known fact amongst railway men, that while nine men in ten may use and not abuse a good idea, the tenth man may bring it into disrepute, and even into disuse, by using it ignorantly. Here we have two distinct systems of brakes, both of them very powerful but badly applied. The steam-brake should have been applied to both sides of the engine, and it should have been put in the power of the driver to have locked the wheel with it. In fact, it is a mistake to place a brake in the driver's hands that can lock the wheels. It may be tested and found capable of doing what is wanted, just as a locomotive boiler is tested and is found capable of standing a pressure double the working pressure. But no one thinks of letting a driver work a boiler at a maximum pressure to wear it out. Why, then, allow the driver to wear the wheels into flat places, and wear out the blocks? Every fireman knows that by a few sudden and smart applications of the brake-blocks to the wheels, followed by the application of a constant moderate pressure, he can stop a train much more quickly than by skidding the wheels. As regards the throttle-valve in the blast-pipe, it should have been made so that it was impossible, at any rate of speed, to arrest the pistons of the engines by closing it. The consequence of skidding the wheels was a loss of retarding power, or a loss of friction.

Friction is the resistance experienced when one body is rubbed upon another body. Friction, while it does not increase with the extent of rubbing surface, increases with the velocity. The friction generated during each revolution of a wheel is the same with a given constant pressure of the brake-block, whether the wheel makes two hundred or four hundred revolutions per minute. In the latter case, however, there are twice the number of revolutions made that there are in the former case; and therefore, though the friction per revolution is the same, the friction per minute is doubled. If a brake is suddenly applied the number of revolutions of the wheel per minute are rapidly reduced, and also the amount of friction; and if the brake is suddenly released the rotation of the wheel increases until it makes the same number of revolutions per minute as the unbraked wheels. We again apply the brake to the same wheel, and instead of applying the block to a surface traversing at the same rate as before, when the brake was taken off, the surface revolves at a higher rate, and there is an increased development of friction-surface.

It does not signify how smooth two rubbing surfaces may look to the eye. They are rough; if you will, they are as rough as a rasp. Imagine two such rasps, called, one of them a wheel, and the other a brake-block; the former in motion, the other fixed. The touching points of one surface must mount upon those of the other, and a number of such little obstructions must act as a retarding power. More or less of this will depend upon the pressure which forces the two surfaces together, causing them, so to speak, to partly interlock. But they wrench themselves asunder. Additional pressure is applied, and then they are pressed so closely together as to effect a final hold of each other, owing only to the adhesive power of the metal. The wheel skids; friction is proportionate to the number of these touching points, and the force which presses them together. The number of touching points between the surface of a brake-block and the wheel are exceedingly more numerous than the touching points between the tread of the tyre and the rail; and when a wheel skids the rail becomes a brake-block, and the total weight supported through the wheel by the rail is the pressure which forces the wheel and the rail together. It is obvious, that in proportion as the two surfaces are dissimilar, so is the element of friction, and the retarding force.

CHAPTER III.

CONDITIONS OF A PERFECT BRAKE.

We were able to travel as fast thirty years ago as at the present day; but we have now, in the year 1881, accumulated experience in proof that by running as fast without the means of pulling up more quickly than formerly, we are not working so safely. There is an increase of traffic, which means more trains, more wear and tear, both to vehicles and to the permanent way; and, therefore, we are liable to more fatal accidents. It is consequently necessary to seriously consider the best means for quickly reducing the momentum of fast trains, and it is only within the last few years that we have really thought of abandoning the rude and primitive contrivance of turning handles in different parts of a railway train for a more mechanical plan of applying brake-blocks to every vehicle in the train.

It is extraordinary that this plan was not adopted at first, or that the speed of trains was not curtailed by Act of Parliament. It was in consequence of the want of better means of applying brake-power, that the signal arrangements have become so complicated, and signal-boxes placed here and there on the side of the railway embankment; with the disadvantages of extra outlay and of difficulty and uncertainty in working; of the signals being placed out of sight of the signalman, and of employing electric repeaters in the cabin to indicate whether the arms of the signals are working, and that special brake-vans are employed, with extra guards. All this means an enormous amount of increase in risk. For want of a larger proportion of brake-power, much time is lost on every journey, and engine-drivers are compelled to slacken speed at long distances from points of stoppage. The more frequent the stoppages, the greater is the time that is thus consumed. It is well known that, of many of the railway accidents of magnitude that have hitherto occurred, the origin was to be found in some train losing time. This cause is chiefly applicable to the drivers of goods-trains, who lose time in stopping a train of 40 waggons by having no other means than a hand-brake on the engine, and by the guard applying his brake on only four wheels of his van.

There is no doubt that we are even now going to work in an odd sort of fashion. If goods trains have been the cause of nearly all accidents, one would think that we should try and get them out of the way or off the road sooner, by applying more brake-power to them. We are doing nothing of the sort; the goods are where they have always been—crawling along; in fact, the goods trains get worse and worse. Although the fact has been patent that the number of accidents can be enormously lessened, if not totally extinguished, by employing continuous brakes, yet there is no other subject so hotly contested in the railway world at the present moment as to how to do it. Not only is there diversity of opinion, but there are also prejudices, and feelings, and interests at stake, which tend to prevent the plain truth from being agreed upon. Each Board of Directors has confidence, more or less, in its own technical officer, and looks at the matter through his opinion or his written report. These officers according to their opportunities, their special knowledge, their qualifications, or their experience, have formed honest, and, in many instances, very different opinions.

As in the construction of engines, and in engine work, each engineer has his own design, so also he has committed himself confidently to some system for stopping his trains. Now the first condition required in a good system of brakes, is the means of applying it from the front, from which position danger is, as a rule, first seen. It is the engine-driver's duty to regulate the speed, to look out for signals or obstructions, to bring the train to a stand at the required point in a given time—in fact, to act with promptitude; in a case of emergency to have the train under his control. Having the responsibility, he ought clearly also to have the power of directing the movements of the train, and be able to reduce the speed or to increase it at his discretion. When he sees danger ahead, he ought not to be obliged to trust to the guard to apply his brake, for he might be dead or asleep. In reply to a warning from the engine-whistle, no fact is more certainly established, than that the guard, after the train is stopped, tells the driver he did not hear the whistle.

As one of the very numerous instances of the want of immediate action on the driver's part, we may mention a case which occurred on the Somerset and Dorset Railway. In this instance, an up-passenger train for Bath was travelling at a speed of 35 miles an hour, when the leading wheels of the engine left the rails, owing to a defect in the permanent way. The engine ran thus for 200 yards before the driving-wheels left the rails. It then turned over on its side at a point 240 yards from the point of first disturbance. The engine-driver was killed, and the fireman and the guard, who narrowly escaped with their lives, were severely injured. If the driver had been able at once to apply a continuous brake throughout the train on finding the leading wheels of the engine off the rails, the train might have been pulled up with scarcely any damage, and no one might have been killed or injured. The engine-driver should be able himself to bring immediate action on the train when necessary, by some process easy to himself and always certain in its effects. Another condition indispensable for a good system is that the guard should also have the power of setting the same force into immediate action when required—on the failure of a wheel in the centre of the train, or when one of the passengers is endeavouring to escape from an assailant. Not many years ago, a young lady rode on the step of a carriage for some miles before the guard who saw her could command the driver's attention.

Again, a good system includes automatic action; that is, in case of the failure of a coupling-spring, axle, or tyre, so as to cause the train to part asunder at or near the middle, the separation of the train should bring about the immediate action of the brake without the intervention of the driver or the guard.

In order that this condition may be properly complied with, each carriage must carry its own brake-power, and it should not be dependent upon power supplied from any other vehicle. The necessity for this condition has been proved in numerous instances. Two of the most serious accidents in this country as regards the number of deaths caused by them, occurred in consequence of the fracture of a coupling and the running back of carriages down inclines, those namely at Brierly Hill, on the Oxford, Worcester, and Wolverhampton Railway, and at Helmshore, on the East Lancashire Railway. At Morpeth, in consequence of the defective condition of the permanent way, the train left the metals and parted asunder. The rear portion drove at a speed of 25 miles an hour into the front portion, and three carriages were so utterly destroyed as to be undistinguishable. The wheels of one of them, together with the remains of a passenger, were taken out afterwards from the tank of the tender, into which they had been driven. Five passengers lost their lives.

Without multiplying instances, it is sufficient to state that hardly any accident of a serious character takes place with separation of the couplings between the vehicles, in which it would not be an all-important advantage for each carriage to act for itself at once without waiting for the driver or the guard to act upon it.

This desideratum will be easily understood when it is remembered that the destruction to the vehicles and the loss of life to the passengers on such occasions is commonly caused by the hind carriages running forward, when on a descending incline, with accumulating momentum upon the front carriages. Another feature of a good system is that it must be its own tell-tale. This, in the eyes of an engineer, appears just as necessary as to have a steam-pressure gauge on a locomotive-boiler. Under a bad and rotten system, a train may be started with the brake-apparatus not coupled up, or with its parts out of order, unknown to the driver when he starts on a journey; and he may only discover that his brake is defective when he finds that the floods have washed a bridge away and he wants to pull up the train before the engine and the train can go down and drown the passengers.

Another important condition of a good system is promptness of action, or application with the full pressure of the blocks to the wheels within a few seconds. The necessity for this requirement will be at once realised when it is remembered that, in one second, a train travelling at 60 miles per hour passes over 88 feet; at 45 miles an hour, 66 feet; and 30 miles an hour, 44 feet. A train travels 100 yards, at 60 miles an hour, in 3·4 seconds; at 45 miles, 100 yards in 4·6 seconds; and at 30 miles an hour, 100 yards in 6·8 seconds. When an accident occurs in which a carriage leaves the rails by failure in any portion of a train, it may be of great, and even of vital importance, immediately to reduce the momentum of every part of the train, and every extra second expended before this action is commenced may involve a case of life or death.

When an engine-driver observes an obstruction 100 yards or 200 yards in front of him, the instantaneous application of his brake will, if it cannot prevent, materially reduce the damage caused by collision. It will save the passengers from injury, and will avert all risk of the subsequent rebound of the buffers, which is often the cause of the worst damage—even when a collision ensues.

At the collision at Saltney, on the Great Western Railway, where the engine-driver of a passenger train was warned by an engine-driver travelling in the opposite direction of an obstruction in his way in the dark, 328 yards from him, caused by some waggons having, in the process of shunting, been thrown from a siding; the passenger train might, by the instantaneous action of a good continuous brake, have been stopped within the distance.

Another point of great importance is simplicity of working, which is a different thing to simplicity of construction. At the opening of a mine or a water-works or pumping station, we sometimes read of Lady Puff having taken hold of the starting lever, and, by a gentle pressure of the hand, put the whole of the gigantic machinery into motion. Nobody will deny that there is a vast amount of complication in the machinery, in the parallel-motion, valves, and condensers. In fact, beneath the floor there seems no end of bell-crank levers, buckets, cocks, and spanner handles. But there is a remarkable contrast in the working, it is in fact so simple that a child can start or stop the movements.

Even so with a brake. Whatever its construction may be, one thing is certain, and that is, it must work with great simplicity. Simplicity as regards the application of railway brakes is not obtained by the system now more commonly employed of turning handles and twisting oneself into an uncomfortable position. There is not only hard and laborious work required to put the brake "*on*," but there is a second dose of strength demanded to take it "*off*" again when required. The operation is barbarous and out of place in these advanced times, when an ounce of steam can do the same thing in less time, and do it better.

Lastly, the workmanship of a good system must be of the very best. A brake is a life-saving apparatus, and therefore the materials must also be of A 1 quality, to stand knocking about, and to be eminently durable.

CHAPTER IV.

THE SCREW-BRAKE.

The application of the steam-brake was not generally entertained, as the question arose whether, in the hands of the drivers, it was not holding out to them an inducement to convert into a source of danger what was intended to be used for public safety. Men will never be otherwise than fallible, and, in view of this, railway companies have always reduced in all ordinary cases what might be a risk of accident to a possible risk of delay. When the sheet-iron screen for drivers on the locomotive engines was first talked about, any one who had courage and sense enough to express himself in favour of its general adoption, was put down a notch by the argument that, without screens, even when the driver has a full view of the track, accidents of a serious kind occur, and what indeed would be the result if you lull the driver into false security by warmth and comfort within a "cab." To speak mildly, it is an abominable idea. This was the opinion of the majority of the Stephenson-made engineers. The young men, the second generation, were more advanced. For years, the guard rode outside on the top of the carriage, where he was supposed to see over the engine, and to see everything before his train, but this outer barbarism cut the men's eyes out with engine-coke, and the priming marks made him a black-and-white spotted non-conductor. He was too blind to give attention, and too black for refinement.

At last, after a good deal of "bowie knife" work, the young blood had the best of it, and the man was placed inside, but it was believed by the older officials to be the beginning of an ingenious invention for producing caoutchouc jaws, glass eyes, silver cranium, platinum noses, and artificial arms and legs by the dozen. A ludicrous effect was produced by a sketch in which the driver is represented rapping, by means of a brass knocker on the guard's van door, and pulling a side bell, in order to inform the guard that they were in front of a bull on the line, and would he please give instructions what was to be done.

It illustrated human nature out in the cold, and in the full force of the storm, looking with envious eyes on another as snug as a passenger.

The argument has been put forward over and over again that the brake-power should be distributed between two or three men in different parts of a train; and, wholly or partially, this opinion has prevailed. But, when collisions have occurred from trains entering stations at too high a speed, the guard has as often accused the driver of running too recklessly, as the driver has accused the guard of neglecting the brake.

As a matter of fact, the screw-brake was relied upon in preference to the steam-brake. Experiments were made on the East Lancashire and Lancashire and Yorkshire railways by Mr. Newall and Mr. Fay to make the screw-brake continuous, and brake-blocks were applied to every wheel in the train. A coiled spring was put into compression by the action of the guard in the carriage before the train started. At any time afterwards, if the brakes were to be applied, the guard had merely to release the springs, and the whole of their power was at once put upon the wheels.

In this way screw-brakes were made continuous and instantaneous in action, but they had the cardinal defect of being in the wrong hands, namely, that of the guards, instead of being in the hands of the drivers: notwithstanding the glaring fact that the driver of a stage coach had the brake-power placed so that he could apply it at his pleasure.

How ridiculous it would have been to have heard the driver shouting to the conductor, "Hold on! hold on! we shall be in the ditch!" However, as a matter of historical accuracy, the screw continuous-brake was, when made continuous, a very powerful train-stopper, and that in advance of all others. It consisted of a shaft extending from one carriage to another, the revolutions of which screwed up the blocks upon the carriages to which they were applied. This shaft is put into operation by means of hand-gearing in the brake-vans; and it may, therefore, be considered merely as an extension of the old hand-system, converting the carriages into so many brake-vans, all of which are placed under the control of the guard, who, when putting his own brake on, applies also those on the carriages. It is evident that, in order to exert his power effectively throughout an entire train of, say, 200 tons weight, a considerable quantity of gearing would be required to multiply the power to the extent necessary for forcing the blocks against the wheels.

This occupied some time, and while the power was being accumulated, time was being lost in stopping.

But the results obtained had never been exceeded before. This form of screw-brake was employed with unique advantage on railways with inclines; and, in fact, many companies applied it—some to the whole train, others to only two or three carriages; but the system of placing the brake-power in the second horseman's hands instead of in the first horseman's hands absorbed seventy-five per cent. of its value. So much for fancy and prejudice.

It has already been mentioned that the screw-brake could be brought into action by means of coiled springs, and that it had the advantage of rapid application: but it required constant adjustment to insure that the blocks should touch the wheels simultaneously, and should act with equal force. It will be seen that many of the conditions required of a good brake are not fulfilled in the continuous screw-brake. The chief defect is the fact of its being employed by the guard only; and there is the defect that it is not automatic, which is a most important principle of action where there are steep gradients.

CHAPTER V.

CHAIN-BRAKES.

CHAIN-BRAKE No. 1.

THE advantage of a continuous-brake was clearly demonstrated by the efficiency of the screw-brake for ordinary working.

It possessed much greater retarding power than any previous brakes; and this fact set men thinking, for it supplied the means of stopping quickly; and where there were many stoppages to be made, it enabled the driver to run more quickly up to a stopping station.

There was another thing, when hand-brakes were used, say, in the front-van and the rear-van of a train: the wheels of these two vans required to be taken out about every eight or ten weeks to be turned up in a lathe, in order to remove the flat places made in them by skidding, and to restore the tyres to circular form.

The great destruction, not only of the wheels themselves, but also of the carriages and the rails, and the loss of the use of the carriage, were evils which were largely reduced by the use of continuous brakes, by means of which a lighter pressure was put on more pairs of wheels than previously. The railway officials were not slow to appreciate this advantage, from a commercial point of view, and a chain-brake was invented by Mr. John Clark, consisting of a chain running underneath the carriages and passing under and over pulleys.

One end of this chain is secured to the end of the furthest carriage upon which it is required to exert its influence, and the other to a revolving shaft on the brake-van. This shaft carries a friction-drum which, being put into motion, winds up the chain, and thereby the levers on each carriage are raised and the brake applied. On the axle of the brake-van is also a friction-drum, and in order to apply the brake, it is only necessary to bring the two portions of the drums into frictional contact. The chain is wound up on the shaft, and the brake is thereby applied. The brakes are put into operation by the guard by means of a weighted lever, which, being released by the trigger supporting it, brings the two frictional surfaces of the drum into contact. It will be seen that, having simply to release the trigger, this brake is capable of very quick application. At 60 miles per hour, a 3 ft. 6 inch wheel makes 7·3 revolutions per second; and supposing the friction-drum to be of the same diameter, and the shaft upon which the chain is wound to be 4 inches in diameter, one foot of chain would be wound up for every revolution of the shaft, or 7·3 feet per second, provided there was no slip in the friction-drum. If the slack amounted to one foot upon each carriage, the brake would therefore be applied on seven carriages in one second of time at 60 miles an hour, and in two seconds on fourteen carriages. The efficiency of this brake depends, first, upon the vigilance of the guards; and secondly, upon the friction or bite of the drum necessary to keep the chain taut. In the application of this principle, it has been customary to extend the chain only to a certain number of carriages at each end of the train, and to place the two sections of carriages so connected under the separate control of the front guard and the rear guard. The chain-brake can be applied by the driver by means of a cord communication as shown. This cord can be carried the entire length of the train, and attached to the triggers supporting the levers in the brake-vans. Upon pulling the cord from the engine, the triggers are released, and the brakes applied by the falling of the weighted levers which press the parts of the friction-drum together. When the train is accidentally divided, the cord is pulled into tension, and the same result follows as though the driver pulled the cord; but should the division take place between any of the carriages connected together by the chain, the brake on that portion would not be applied because the power would be lost. If the chain were extended the whole length of the train, the brakes could not act automatically in the event of the train separating, although the levers would be released by the breaking of the cord, because the chain would be loose and the friction-pulleys would have nothing to tighten against.

In the application of this principle it is, therefore, necessary to divide the train into portions, so that the whole power may not be lost by any accidental breaking of the chain. By this arrangement the driver can apply the brakes by pulling the cord, but they must be taken off by the guards, thus making the working of the brakes a matter of divided responsibility.

This brake cannot be put on gradually. When the trigger is released it is at once fully applied sufficiently to skid the wheels in all kinds of weather. This is a matter of very great importance.

In dry weather the friction between the wheel and the rail may be set down as one-third of the weight upon the wheel. On a humid rail—neither wet nor dry—the friction is about one-tenth of the weight. It is clear that to pull up with the greatest possible rapidity, at all times, there must be power sufficient to apply the greatest pressure required under any circumstances.

Evidently, the conditions which have been formulated for a good system of brake, are not to be found in the chain-brake. It has certainly one very good feature in it, and that is, the driver can use it well in an emergency, but it is not automatic, and therefore it fails where the cardinal quality of a good brake is required, namely, when a train is derailed, or is pulled asunder by an inexperienced driver, through the opening of the regulator of the engine at random.

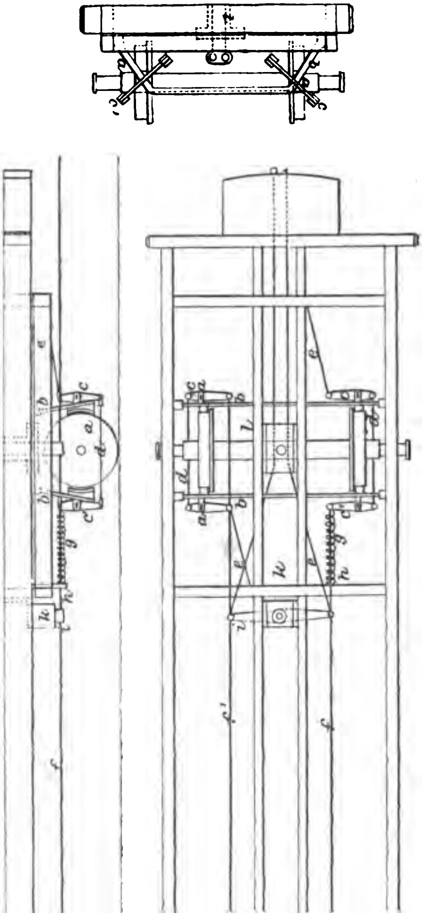
Chain-Brake No. 2.

The No. 2 form of chain-brake is constructed on the principle of keeping the chain constantly under tension, whereby weighted levers or springs, which are employed to apply the brakes on each carriage, are kept out of action. The brakes in this case are applied by relaxing the chain; and it is evident that, as the power for applying the brakes is furnished by the levers or springs on each individual carriage, the automatic action is obtained by the breaking of the chain in any part of its length. This arrangement, however, requires means of winding up the chain and keeping it in tension, which is done by means of a winding-up apparatus in the brake-vans, and so long as trains are attached to such vans, this is practicable, but it would be difficult to apply such an apparatus on each carriage so as to be conveniently worked when the brake-van is not available, and at the same time to provide for the free control of the chain from the vans, when the train is made up complete.

Clark's Chain-Brake.

Clark's chain-brake is shown in Figs. 5, 6, 7, as applied to the frame of a railway-carriage. *a* are the brake-blocks fitted to the pendulous brackets, *b*. The levers, *c*, *c'*, jointed to the brackets, *b*, are connected at their lower ends by pulling-rods, *d*. One lever, *c*, of each pair is held by a pulling-rod, *e*, to the frame of the carriage as a fulcrum; and the other levers, *c'*, are jointed to two tension-rods, *f*, *f'*. Upon the tension-rods, two or more spiral springs, *g*, are fitted in such a manner that when the tension-rods, *f*, *f'*, are pulled, by screws or other suitable apparatus fitted on the guard's-van or engine, they compress the springs which rest upon brackets, *h*, attached to the frame of the carriage. When the springs are compressed the brake-blocks, *a*, are drawn clear of the carriage-wheels, and by the recoil of the springs, *g*, the blocks are pressed upon the wheels, and the brake is applied.

This result may either be attained by releasing the tension-rods, *f*, *f'*, by the apparatus in the guard's-van by the engine-driver, or in the event of the train breaking away accidentally the recoil of the springs will apply the break automatically. The rods, *f*, *f'*, are jointed to levers, *i*, working on fulcrum-brackets, *k*, attached to the framing of the carriage, so that when one of the rods, *f*, *f*′, is pulled in the manner already described, the other rod is also pulled, and thereby the brake is applied on both sides of the carriage simultaneously.



Figs. 5, 6, 7.—Clark's Chain-Brake.

To enable the tension-rods, *f*, *f*′ to work along a train over sharp curves, they are so fitted as to converge at or near the fulcrum-pin, *l*, where they may be jointed to radial links to guide them; or they can be formed of steel-wire rope, and be passed through holes in the head of the fulcrum-pin. The ends of the rods, *f*, *f'*, are formed with right and left-hand couplings.

Fig. 8 shows the arrangement to regulate the friction-wheels used for tightening the chain of the brake. *a* is a longitudinal rod jointed to the pendulous-lever, *b*, and sliding in a check-plate, *c*, fixed to the frame of the carriage. When it is required to keep the friction-wheel, *d*, out of contact with the drum, *e*, upon the axle, *f*, a detent, *g*, is placed in the gap, *h*, of the rod, *a*, and thereby prevents the said rod from sliding in the check-plate, *c*, and thus keeps the friction-wheel, *d*, out of contact with the drum when so required. A similar arrangement is fitted to the friction-wheel, *d'*, for the same object.

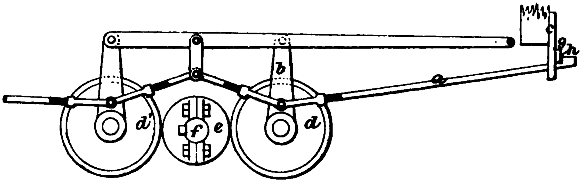
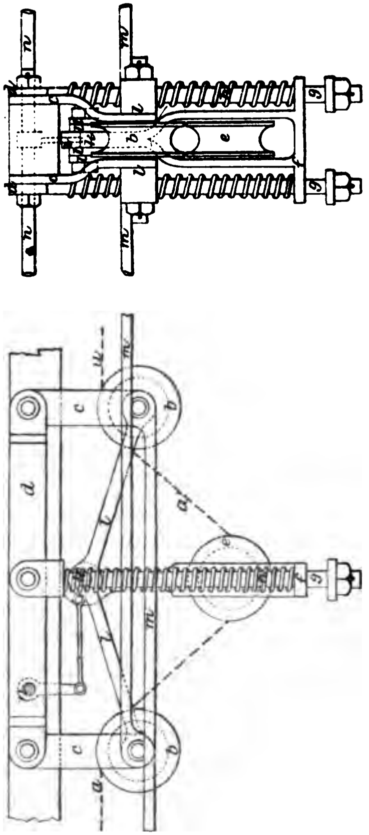


Fig. 8.—Clark's Chain-Brake—Friction-Wheels.

The mode employed by Mr. Clark to work chain-brakes automatically, in the event of the train dividing accidentally, is shown in Figs. 9 and 10. It may also be used for working such brakes negatively for ordinary stoppages. The through chain is wound up and kept tight by suitable gear in the guard's-van or the engine, while the train is running, and the brake-blocks are thus kept from pressing against the wheels. But when the brake is required to stop the train, the chain is slackened, and, by the recoil of springs on each carriage, the brake is applied. *a* is the chain, supported on pulleys fitted to the carriage under frame.

Two chain pulleys, *b*, are fitted in pendulous links, *c*, from brackets, *d*, which are also fitted to the under-frame of the carriage. The chain pulley, *e*, is fitted to a bracket, *f*, which slides upon the two vertical rods, *g*, upon which are placed the spring, *h*. The bracket, *f*, is fitted with a hook, *i*, which hooks upon the fulcrum-pin, *k*, of the compound links, *l*. In this manner, when the chain, *a*, is tightened by means of friction-wheels worked by contact with the van-axle or another axle of the train, the chain-pulley, *e*, is raised, which compresses the springs, *h*, and raises the pin, *k*, so that the pulling-rods, *m*, keep the blocks out of contact with the wheels of the carriage, so long as the chain, *a*, is kept tight. But, if the chain gets broken by reason of the train dividing accidentally, or if it be slackened by any



Figs. 9 and 10.—Clark's Chain-Brake—Automatic Action.

means for the regular stopping of the train, the springs, *h*, recoil and apply the brake with the force stored in them. *n* is a rotating-rod or lever which is connected to the hook, *i*, to disconnect the brake from working when it is not required.

Conclusions.—The Clark chain-brake, as described, is a modification of the Clark chain-brake as used formerly, which has been applied to a great number of railway carriages in this country. But it has the great defects of all chain-brakes:—1st. That it can only be used on very short trains, or portions of trains, so that it is practically a sectional brake rather than a continuous brake. 2nd. The action cannot be controlled; that is to say, when applied, the action is in full force, because the friction between the pulleys cannot be graduated. On account of this, chain-brakes will at all times be very rough brakes. 3rd. It is influenced by changes in the weather, and it very commonly happens that drums and pulleys become coated with ice in winter. The friction-pulleys, under such circumstances, lose entirely their grip, and the brake is rendered powerless. 4th. It not unfrequently happens that in winter the chain gets frozen fast on its guiding pulleys. In this case, the brakes cannot be either applied to or taken off the wheels. 5th. This brake, as generally fitted in this country, is, for the convenience of the traffic, worked from the van, and not by the driver. Evidently, this is a bad practice, that is sure to lead to disasters, as has been the case in many instances.

It may be added that the chain-brake is very old, and that it has been tried more than any other brake; and if this brake were a really satisfactory solution of the problem, it would have become, ere now, the universal brake of the world.

CHAPTER VI.

SMITH'S VACUUM-BRAKE.

SMITH'S vacuum-brake is a non-automatic brake, consisting of a line of pipes coupled between the carriages, with flexible couplings. Each carriage has one or more flexible chambers in connection with the main pipe, the flexible part being attached to the brake-levers. To apply the brakes, the air is drawn from the main pipe and flexible chambers by means of an ejector placed on the engine, and a jet of steam from the boiler. The flexible chambers collapse under the external atmospheric pressure, and exert a certain pulling force on the brake-rods.

The method of mounting the apparatus on the locomotive and tender, and of applying it to them is illustrated by Plate I. A is a single or double ejector, placed in a position convenient for exhausting into the smokebox of the locomotive; B *b* is the starting-valve and pipe leading to the ejector; C *c*, the handle and rod by which the driver opens the steam-valve to apply the brake; D *d*, the air-valve to release the brake, and pipe leading to pipe-service through the train; E, the vacuum gauge; P *pp*, the pipe-service from sacks to ejector; S, the sacks or collapsing cylinders.

In Plate II. the application of the vacuum-brake to

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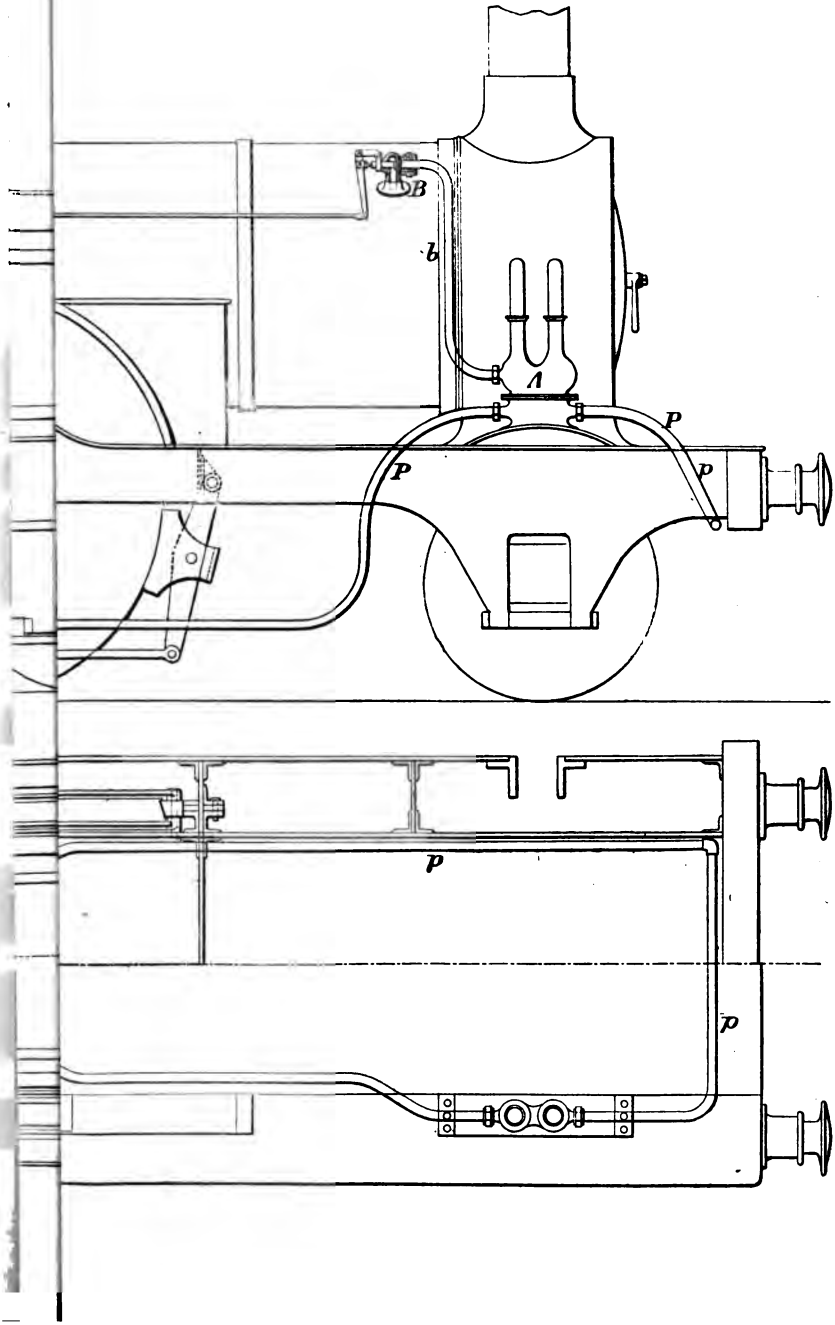

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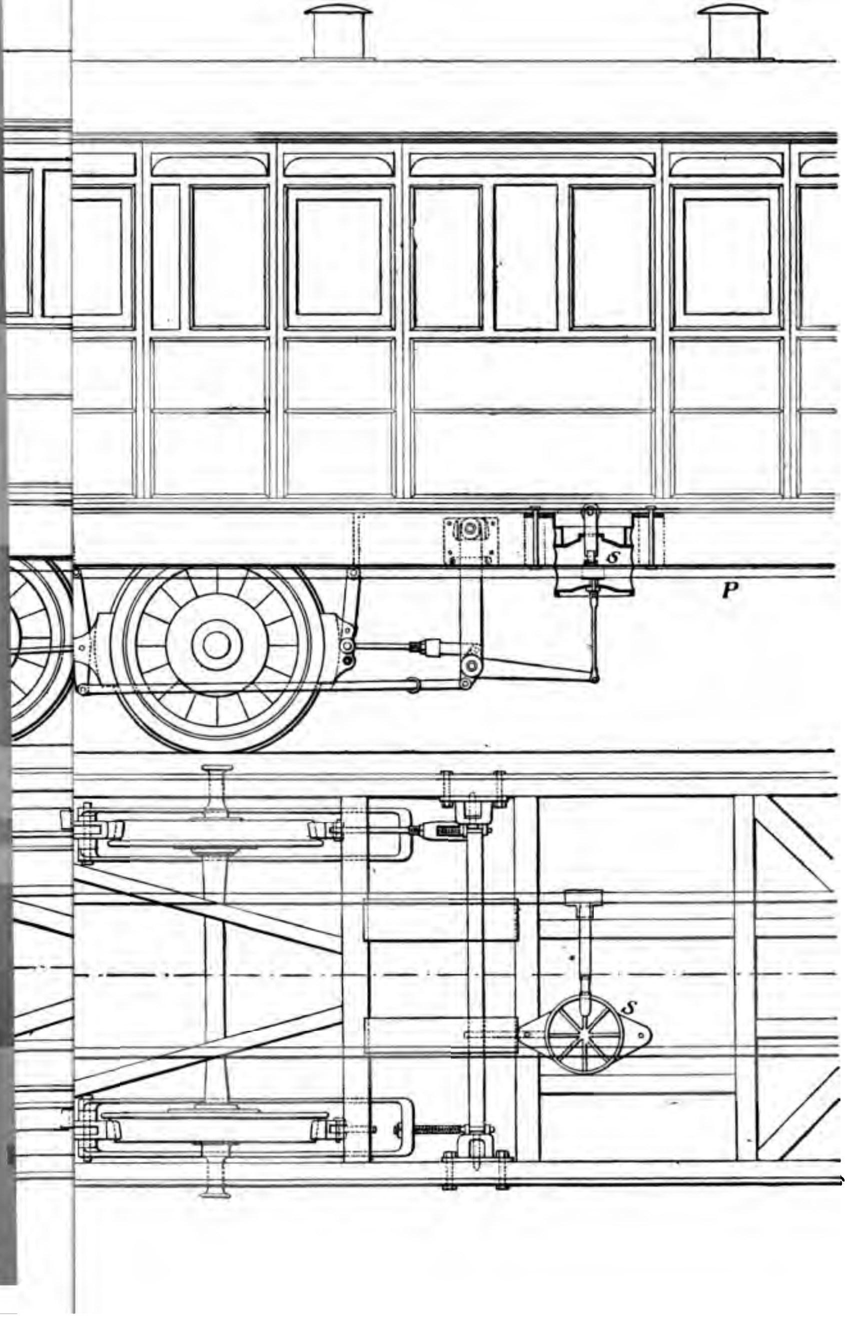

σ
P
S

the luggage-van and to the carriages of the train is illustrated:—P is the pipe-service through the train from the sacks to the ejector; H, the hose and coupling between the carriages; S, the sacks or collapsing cylinders.

The brake, being non-automatic, is powerless if the couplings between the carriages become undone, or if the flexible chambers give way by wear and tear, or if the main pipe breaks. Like all other non-automatic brakes, it has the disadvantage of becoming powerless in case of accident, because the first shock generally breaks a part of the apparatus, and thereby releases the brakes at the very instant that they are the most needed. This has been shown in many accidents to trains fitted with the Smith's vacuum-brake. The brake is powerless also in the case of a train breaking loose on an incline; the rear portion runs back without the driver knowing it, and without anybody being able to stop it. Such cases are extremely dangerous, and result almost invariably in serious accidents.

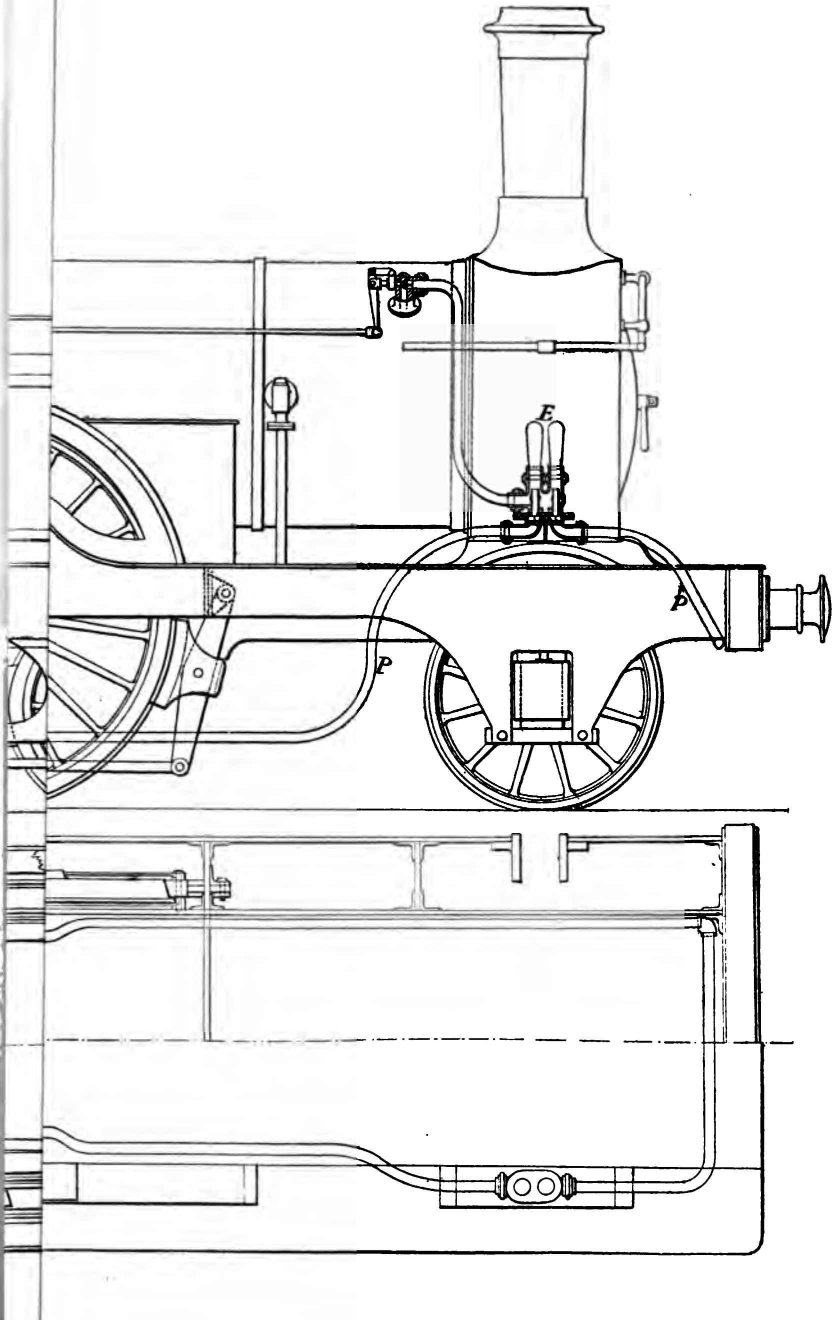
CHAPTER VII.

HARDY'S VACUUM-BRAKE.

THE general principle of Hardy's vacuum-brake is identical with that of Smith's. The points of difference are as follow:—The ejector is always *double*, and is specially constructed to act upon the engine and tender independently of its action upon the carriages. The action is simultaneous, one steam-jet only being used. By this arrangement the engine and tender brakes are not rendered ineffective should the hose between tender and train be left uncoupled. The use of the double ejector also insures much better stopping results in case of emergency, &c., and it is unquestionably a valuable improvement. The vacuum-chamber or cylinder is also of a very different design. In the brake under description, the flexible portion is of leather, which is completely protected by an iron casing. This form is greatly preferred by many engineers, especially for application to locomotives and tenders. A single line of pipe is also a speciality of the Hardy system.

The general arrangement is illustrated by Plate III.: E, ejector, double-acting, shows chambers separated by partition; P, pipe-service to the train; P′, pipe-service to the engine and tender; C *c c*, vacuum cylinders; *c c*, show leather in section.

PLATE III.



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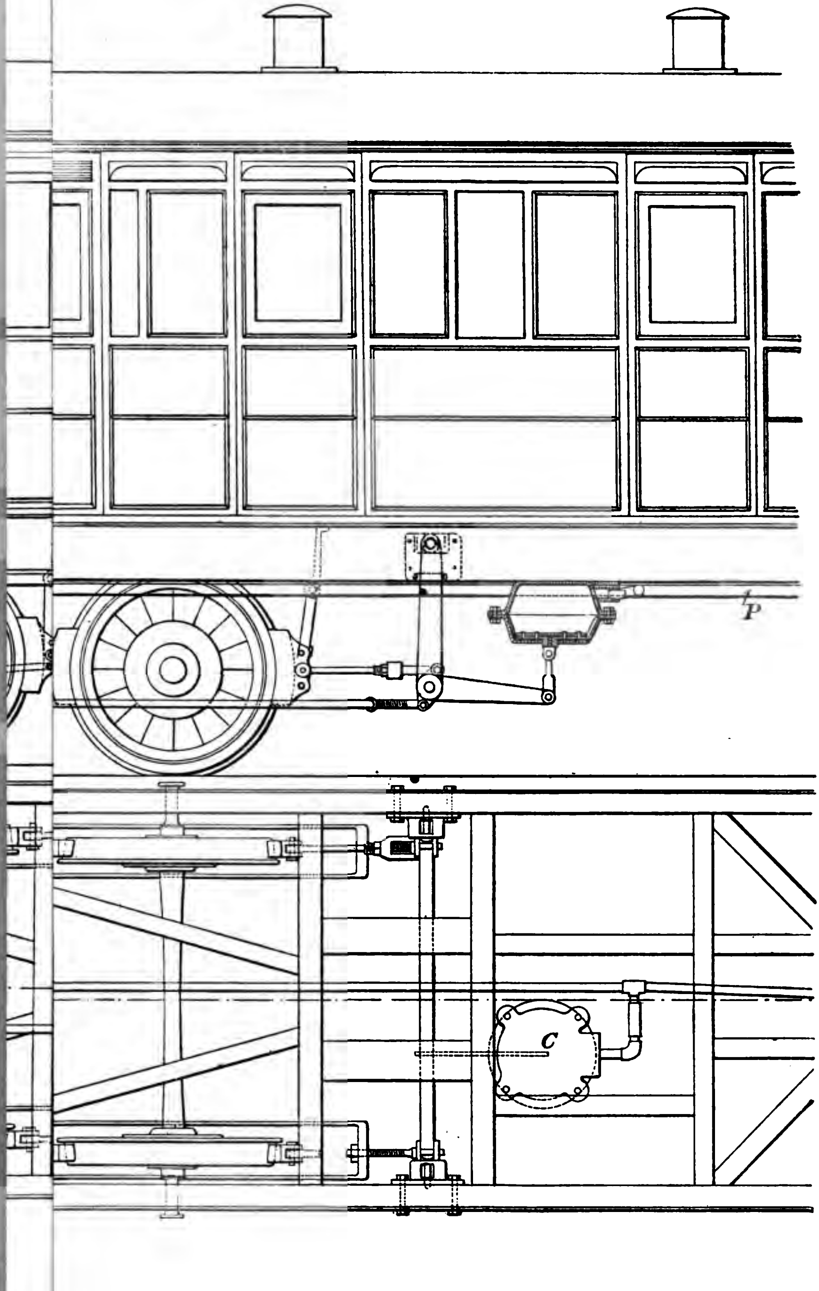
P
C

The application of the brake to the luggage-van and to the carriages of the train is shown in Plate IV.: C, vacuum cylinders; P, pipe-service (*single*).

HARDY'S AUTOMATIC VACUUM-BRAKE.

In this apparatus, a vacuum is maintained in the main pipe and reservoirs under the carriages by means of an ejector on the engine. These reservoirs carry valves so constructed as to establish a communication between the flexible sack and the reservoirs as soon as the vacuum in the main pipe is destroyed. The ejector on the engine is so combined with a flexible sack and steam-cylinder as to maintain automatically a vacuum in the main pipe.

The attachment on the engine for automatically maintaining the constant vacuum is show in Plate V: A, the ejector as ordinarily placed; B, the starting valve; D *d*, the handle and pull-rod for opening the starting-valve; E, the air-valve for *applying* the brake; C, small vacuum-cylinder or sack; S, small steam-cylinder for opening the starting-valve; V, intermediate small steam-valve or stop-cock for supplying steam to the steam-cylinder S, and opened and closed by the vacuum-cylinder *c*; O, stop-cock in the pipe leading from the cylinder *c* to the pipe through the train; X, exhaust pipe from the steam-cylinder S; T, rubber lift-valve, opening only towards the ejector.

This automatic addition has been devised with a view to meet the possible contingency of the Board of Trade requiring from railways the adoption of an automatic brake. The method of working is as follows:—The driver, before leaving a terminal station, opens the starting-valve by means of the handle and rod D *d*, thereby creating a vacuum in the pipes and reservoirs throughout the train, also in the vacuum-cylinder or sack C. This vacuum is ordinarily 24 inches or eight-tenths of an atmosphere; the brakes are then off the wheels, and they remain so until the vacuum in the pipes is lessened or destroyed to a point below one-third of an atmosphere, or 10 inches. To provide against the application of the brakes through any gradual leakage through the pipes, the cylinder or sack C is weighted by a spiral spring or weight, so that by the destruction of 5 inches of vacuum or one-sixth of an atmosphere in the pipes, the valve or stop-cock V is opened, permitting steam to enter the cylinder S, which at once opens the starting valve B, instantly restoring the vacuum in the pipes and sack C, closing the valve or stop-cock V. The steam in the cylinder S then escapes by the pipe X, when the starting valve B is closed by a spiral spring or weight; this action being repeated as often as the vacuum becomes impaired, as described above.

The driver, in the ordinary working of the brake, opens the air-valve E, which action closes the stop-cock O, preventing the destruction of the vacuum in sack C, but destroying the vacuum in the pipes throughout the train, instantly applying the brake. A similar valve E is placed in each guard's van, giving the guard equal facilities of applying the brake. The brake is also instantly applied by the breaking away of any part of the train, or by any accident causing a rupture in any of the pipes or reservoirs. The reservoirs, sacks, and levers are arranged with a view to obtain a power equal to skidding the wheels of a carriage when 24

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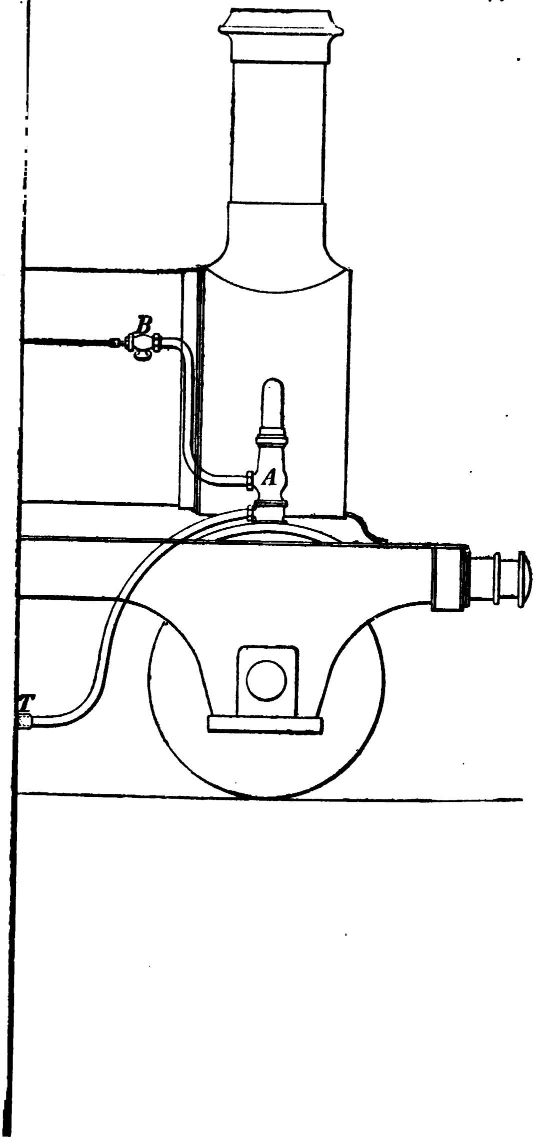
PLATE V.



inches or eight-tenths of an atmosphere is contained in the reservoir; of course, any less amount of vacuum would give a proportionate amount of brake-power. The driver has always the means, through the handle and rod D *d*, to restore the vacuum in the pipes and reservoirs should any part of the automatic arrangement for doing so, upon the engine, become deranged. The driver, by means of the gauge in front of him, can always tell the condition of his brake and what available brake-power he has at his command throughout the train.

The apparatus for a carriage is shown in Plate VI.: A is the reservoir in which a vacuum is created and maintained, the cubical capacity of the reservoir to be in excess of double that of the sack or cylinder used to apply the brakes; B, the ordinary cylinder (or sack), applying the brake in the same manner as without the automatic arrangement; P, the pipe service through the train to the ejector, and pipes or hose connecting the cylinder and the reservoir with the same; D, rubber lift-valve opening outward, preventing the return of air when the vacuum is created in the reservoir; E, the rubber valve, with double seat, having a double function: 1st. To establish in a certain position a communication between the brake-cylinder and the atmosphere through the holes *e*, *e*; and at the same time to cut off the communication between the reservoir and the brake-cylinder. 2nd. To establish, in another position, a passage from the brake-cylinder to the reservoir, closing at the same time the passage from the brake-cylinder to the atmosphere.

There are, however, three functions necessary for establishing a proper relation between the elements of the brake—namely, (1) from the brake-pipe to the reservoir; (2) from the reservoir to the brake-cylinder; (3) from the cylinder to the atmosphere. The two last being provided for by the action of the double-seat valve just described, another valve was found necessary, consisting of a rubber-seat valve, D, at the other end of the reservoir, in order to establish a communication between the reservoir and the brake-pipe when air is drawn from it by means of an ejector placed on the engine.

The operation of these valves is as follows:—Air being drawn from the brake-pipe, both valves are acted upon, and air from the reservoir flows through the single-seat valve into the brake-pipe. The double-seat valve, being attached to a diaphragm of a great diameter, overpowers the action of the atmosphere on the small rubber-seat, and keeps the holes, *f*, *f*, closed, whilst a free communication exists from the brake-cylinder to the atmosphere by the holes, *e*, *e*, keeping the brakes off.

To apply the brakes, the driver admits air to the brake-pipe, thereby destroying vacuum. The single-seat valve closes on account of the atmospheric pressure; whilst the diaphragm of the double-seat valve is pushed forward by the same air, closing the openings, *e*, *e*, from the brake-cylinder to the atmosphere, and opening the holes, *f*, *f*, as a communication between the reservoir and the brake-cylinder. The air from the latter expands into the reservoir, and thereby a partial vacuum is produced, which applies the brakes.

This brake, therefore, is automatic in its action. It must, however, be considered as a very imperfect brake, because the action of the diaphragm-valve does not

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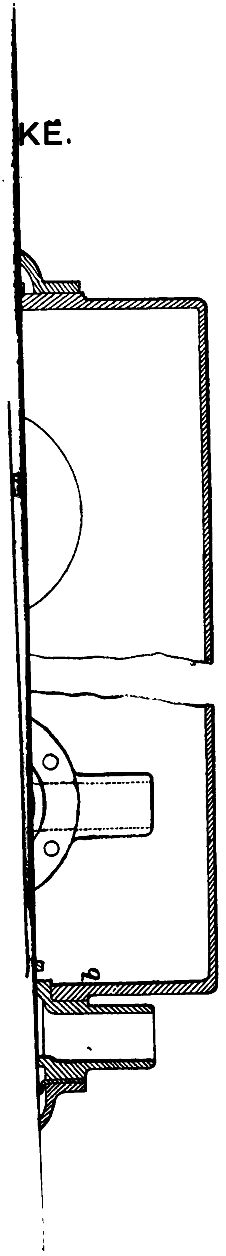
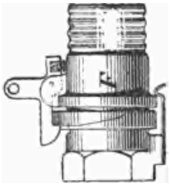
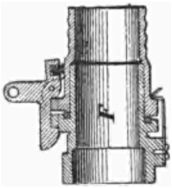
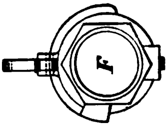
PLATE VI.









allow of the brake-force being graduated at the will of the driver. In fact, the valve must always be over on one side or the other, whilst any intermediate position would establish a free communication between the reservoir and the openings, *e*, *e*, and thus destroy at once the brake-power.

This intermediate position will produce itself on trains of a certain length by a flow of air into the brake-pipe at a certain rate. The valve will then be in a floating condition on certain carriages, and consequently its brake-power will be destroyed.

There is another grave objection: the great bulk of this apparatus. The reservoir must be of an enormous size to give even medium results. In fact, at each application of the brake, a volume of air at atmospheric pressure, equal to the volume of the brake-cylinder, is brought into the reservoir, thereby considerably reducing the partial vacuum in the reservoir.

The couplings, F, designed for this brake, are almost similar to those used in connection with Smith's non-automatic vacuum-brake. With automatic-brakes there is, however, a serious objection to the use of couplings so constructed as to apply the brakes on the whole train when the couplings are taken apart. The inconvenience resulting from this at junctions, and in shunting operations, is self-evident; but more is to be said about this in dealing with other automatic vacuum-brakes.

As a whole, the automatic vacuum-brake, as designed by the Vacuum-Brake Company, must be considered as very imperfect and unfit for practical use. This explains why the Railway Companies who are now using non-automatic vacuum-brakes, and who are anxious to comply with the wishes of the Board of Trade, are so slow in altering their brakes to this new pattern.

NOTE.—It is interesting to compare the capacity of such a reservoir as that of the Hardy automatic vacuum-brake with that of the Westinghouse automatic brake, and a few lines will clearly show the great advantage of the latter system to that described.

The Westinghouse brake-gear is so proportioned that 40 lbs. in the brake-cylinder puts the brake on with full force, say 100 per cent. block pressure.

Automatic Vacuum :—

The cylinders are generally made of the diameter 18 inches, or 4·57 decimetres.

The surface of the piston is therefore 16·4 square decimetres.

To have the same total piston-pressure, we require 7·9 lbs.

The piston movement must be also 6 inches = 1·5 decimetres.

But 6 more inches are required for wear of blocks, and the length of cylinder is therefore 12 inches = 3 decimetres.

The vacuum when starting is not more than 24 inches, or a reservoir pressure of (absolute) 3 lbs.

After the third application the brake must be one with 7·9 lbs. pressure; therefore the pressure at the reservoir-side of the piston, 15 − 7·9 = 7·1 lbs.

Suppose the capacity of the reservoir = x litres.

After three times applying the brake, three cylinders full of air have gone into the reservoir, 3 (16·4 × 3) = 147·6 litres.

It is then easy to calculate what sized reservoir is needed to give a final absolute pressure of 7·1 lbs.:—Three cylinders with air $(147{\cdot}6 \times 15 \text{ lbs.}) \times$ reservoir $(x \times 3 \text{ lbs.}) =$ reservoir and cylinder $(x \times 24{\cdot}6) \times 7{\cdot}1$ final pressure $= 22{\cdot}14 \times 3\,x = 7{\cdot}1\,x \times 174{\cdot}6$; therefore $x = 497$ litres.

COMPARISON OF RESERVOIRS.

The object is to ascertain what size of reservoir would be needed for an automatic vacuum-brake to obtain the same brake-force as with the Westinghouse automatic brake.

The following figures are the data for the Westinghouse brake as now generally applied to passenger vehicles:—

Capacity of small reservoir, 1,475 cubic inches.

Surface of 8-inch piston, 50 square inches.

Useful stroke of piston, 6 inches.

Spare stroke of piston for wear of blocks, 6 inches.

Volume of air used at each application, 300 cubic inches.

Suppose the air pressure when starting to be 80 lbs. per square inch in the reservoirs, after each application it will be a proportion of the pressure $= \frac{1475}{1475 + 300}\,P = 0.833\,P$.

It must, however, be observed that the air from the reservoir drives the piston in front of it, and therefore expands, as if it were acting in an absolute vacuum. The absolute pressure must therefore be considered and afterwards reduced to pressure above the atmosphere.

In accordance with the above remarks the following table is obtained.

	Absolute pressure in reservoir in lbs. per square inch.	Pressure above the atmosphere in brake-cylinder.
When starting	95 lbs.	
After 1st application	79·13 „	64·13
„ 2nd „	65·9 „	50·9
„ 3rd „	55 „	40
„ 4th „	45·8 „	30·8

The proportions of the Westinghouse gear are generally so arranged that by about 40 lbs. pressure per square inch in the brake-cylinder, the brakes are applied with a block-pressure equal to the weight of the vehicle, which must be considered full force. The table, therefore, shows that the Westinghouse brake can be applied three times with full force without re-charging the auxiliary reservoirs.

It must now be calculated what the size of the automatic vacuum-brake must be to secure somewhat similar results. The Eames cylinder being of such a shape that it is rather difficult to calculate its volume, we will, for the sake of illustration, take an ordinary cylinder. This does not alter the figures in any way.

Surface of 18-inch piston, 255 square inches.

Useful stroke of piston	as in the Westinghouse	6 inches.
Spare stroke for wear of blocks		6 inches.

Total capacity of brake-cylinder 3,060 cubic inches.

To obtain on this size of piston a total pressure equivalent to that of 40 lbs. per square inch on the 8-inch piston of the Westinghouse brake, a pressure of 7·87 lbs. per square inch is required. This shows that the vacuum in the brake-cylinder must be after the third application 15 — 7·87 = 7·13 lbs. per square inch.

The vacuum which can be kept constantly in the reservoirs of an automatic vacuum-brake is at the highest 24 inches, but generally not more than 20, which is equivalent to 5 lbs. per square inch absolute pressure. The air pressure, therefore, when starting, is 5 lbs., and must be after the third application of the brake not higher than 7·13 per square inch; and the question is, how large the vacuum-reservoir must be to obtain such a result.

It must be borne in mind that every time the brake is applied a volume of air at atmospheric pressure equal to the capacity of the brake-cylinder is put into communication with the reservoir, and consequently destroys the vacuum partially, by raising the air pressure which it contains.

After the third application, therefore, three cylinders full of air, 9,180 cubic inches in volume, will have been put into communication with the reservoir.

It is easily calculated that a reservoir of 50,337 cubic inches is necessary to satisfy the conditions enumerated. The absolute pressures in the vacuum-reservoir will then be for the three consecutive applications of the brake 5·74 lbs., 6·46 lbs., 7·15 lbs.

A comparison of this enormous reservoir with that used in the Westinghouse brake, and which has only a capacity of 1,475 cubic inches, shows that the Eames reservoir must be $\frac{50337}{1475} = 34{\cdot}1$ times larger than the Westinghouse reservoir.

CHAPTER VIII.

STEEL AND McINNES' COMPRESSED-AIR CONTINUOUS-BRAKE.

STEEL AND McINNES' continuous brake is worked by means of compressed air. It consists of cylinders fitted with pistons and piston-rods placed at each end of each carriage. The cylinders on each vehicle are connected by a pipe at their upper ends; that is to say, at the upper sides of the pistons; and the piston-rods are coupled by means of links, chains, or connecting-rods, to the lever or levers on the brake-shaft, so that as the pistons, with their attachments, are moved upwards or downwards the brakes are applied or withdrawn. The lower part of each cylinder is either of itself sufficiently large to constitute an air-vessel, or it is connected to an air-vessel, with which it forms one piece. From the air-pipe, or from the upper part of the cylinder, a branch-pipe leads to the air-vessel below the piston, and this pipe is provided with a valve, which is opened by the air in passing through the pipe to the air-vessel, so that equal pressures of air are obtained on the two sides of the piston; the valve being so arranged that it cannot be opened by the pressure of the air below the piston. The compressed-air cylinders on the vehicles throughout the train are connected together between the vehicles by flexible piping provided with couplings, which are disconnected when the vehicles composing the train have to be uncoupled. Each cylinder is provided with two coupling-openings, the face of each of which is composed of elastic material. A bracket is also formed upon or attached to the cylinder, and arranged in front of the elastic face and opening. Through this bracket, opposite the opening in the elastic face, a screw is passed, between which and the elastic face a metallic elbow T-piece, having a flat face at each end, and to which the flexible coupling-pipes are attached, is firmly secured by tightening the screw.

This elbow, or T-piece, forms a passage for the air from cylinder to cylinder, and is easily uncoupled by withdrawing the screw which presses it against the elastic face. The air is compressed by means of an air-pump driven by a small steam-engine fixed on the locomotive, from which the steam is supplied. One or more rows of tubes are placed round the tender, and these constitute a receiver for the compressed air, from which it is distributed to the apparatus.

When it is desired to apply the brake, the air acting upon one side of the pistons is withdrawn; and that on the other side, together with the air contained in the air-vessel, being free to expand, moves the pistons in the cylinders so that the brakes are applied. When it is desired to withdraw the brake-blocks from the wheels, the air is readmitted to that side of the pistons from which it had previously been withdrawn, and thus the apparatus is restored to equilibrium, so that by its own weight it withdraws the brake.

By means of this system of brake apparatus, the pressure of air is constantly active throughout the train, and the carriages are provided with whistles, a handle being placed in each compartment. Each handle is coupled by a wire to a lever on the whistle-valve, on pulling which communication is opened between the air-pipe and the whistle, which is thus sounded.

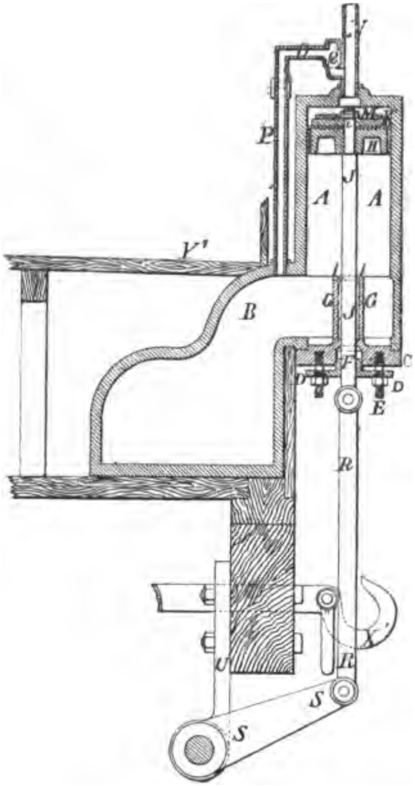


Fig. 11.—Steel and McInnes' Brake—Cylinder and Receiver.

Fig. 11 is a vertical section of a compressed-air cylinder and receiver, with attachments. Fig. 12 is a vertical section at right-angles to Fig. 11; while Fig. 13 is a side view. The cylinder, A, and air-vessel, B, are in one casting. The cylinder, A, is cast with the upper end close, the lower end being fitted with a cover, C, provided with a stuffing-box and gland, D, secured by studs, E; the space, F, being filled with suitable packing.

On the inner side of the cover, C, a hollow cylindrical projection, G, is formed, upon which the piston, H, rests when in its lowest position; that is to say, when the brakes are "off." The projection, G, is

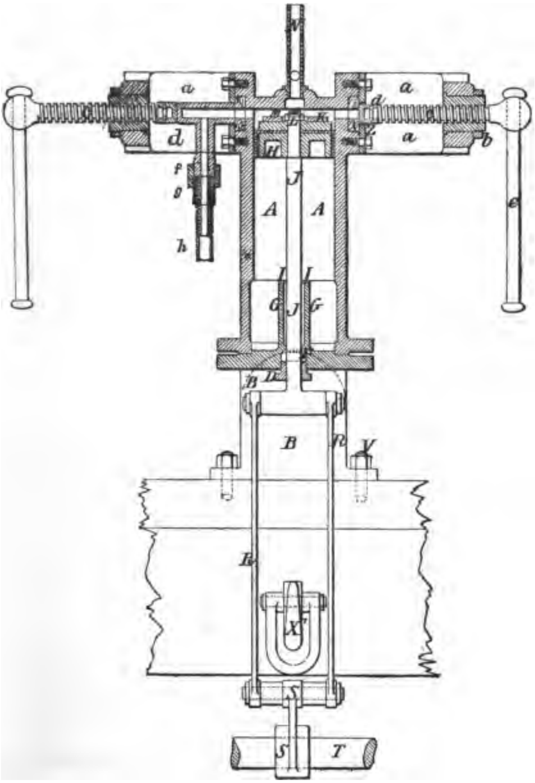


Fig. 12.—Steel and McInnes' Brake—Cylinder.

provided at the top with an india-rubber ring, I, which acts as a cushion to prevent any shock which might arise from the fall of the piston, H. The space between the piston-rod, J, and the interior of the cylindrical projection, G, may be filled with packing to further prevent the escape of air from the cylinder, A. The piston, H, is packed by a cup-leather secured to its upper side by a washer, K, and nut, L, which nut at the same time secures the piston, H, to the piston-rod, J, as shown. An india-rubber ring, M, is placed upon the washer, K, to cushion the shock in the event of the piston striking against the top of the cylinder. On the inlet-pipe, N, is a branch, O, in which is formed a valve-chest and seat, and which is connected to the air-vessel, B, by a pipe, P. A ball-valve, Q, accurately fitting the seat in the branch, O, prevents the air from returning by the valve, G.

The piston-rod, J, is coupled to the brake-apparatus by the connecting-links, R, which are shown double, as in Fig. 12, in order that they may clear the drag-hook, X′. At Fig. 13, the whole apparatus is represented as set further into the carriage, in order that the links, R, may be kept only so far apart as to clear the thickness of the drag-hook. These links, R, actuate the bar, S, fixed upon the brake-shaft, T, which is acted upon according to the movement of the piston in the cylinder, A.

When the apparatus is applied to a vehicle running upon bogies, the brake-shaft, T, is connected to the piston-rod, J, by means of a flexible coupling, such as a chain or connecting-rod fitted with an universal joint, so as to allow for the movement of the body of the carriage upon the swivel-pins of the "bogies."

The brake-shaft, T, is carried in brackets, U, bolted to the lower framework of the carriage. The brake-cylinder and receiver are fixed to the lower framework and floor of the carriage by bolts, V, which pass through a flange formed upon the sides of the air-vessel, B. The air-vessel projects through the end of the carriage, and is situate below the seat, as shown in section Fig. 11. The couplings whereby communication is effected between the cylinders on the different carriages is shown particularly at Figs. 12 and 13. Openings, W, are formed at the upper part of the air-cylinder, A; caoutchouc or other elastic rings, X, fill the recesses formed for their reception in the faces, Y. To keep the elastic rings, X, in their places, metallic rings, Z, are bolted on the face, Y, the interior edges of which rings overlap to some extent the elastic

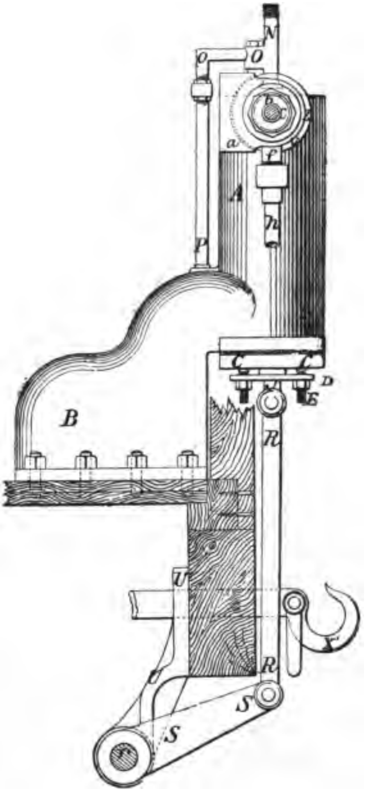


Fig. 13.—Steel and McInnes' Brake—Cylinder and Receiver.

rings, X, and thus hold them in position. Projections, *a*, are formed opposite the faces, Y, and these are bushed with screwed nuts, *b*, through which the screws, *c*, pass, the centres of which are opposite the centres of the opening, W. The inner extremities of the screws, *c*, are provided with anti-friction thimbles, *d*, and the outer extremities with vice-handles, *e*, by which the screws are actuated. A hollow metallic T-piece, *f*, is held between the thimble, *d*, and the elastic ring, X, the pressure imparted by tightening the screw, *c*, being sufficient to insure an air-tight joint between the circular flat edge of the hollow metallic T-piece, *f*, and the face of the elastic ring, X.

The junction of the T-piece, *f*, and the flexible tube, *h*, which connects the cylinders, is effected by forming a nozzle or projection, *g*, upon the T-piece, *f*, over which the flexible tube, *h*, is drawn, in which position it is held by a box-nut and thimble-washer.

On the other side of the cylinder from that on which the T-piece, *f*, is shown at Fig. 12, the screw is indicated as advanced inwards so that the thimble, *d*, presses upon an elastic ring, and closes the opening.

Fig. 14 is a side elevation of parts of a locomotive engine and tender fitted with the necessary apparatus for operating the brake. An air-pump is bolted to the fire-box of the boiler, and it is driven by a small steam-engine situated on the other side of the fire-box —not seen in the drawing—which drives the crank-shaft. Air is pumped through the tubing, B, into the tubular receiver, C, on the tender. On a branch-pipe, D, projecting from the receiver, C, is fastened a two-way cock, E, by means of which the pressure of air from the receiver, C, may either be directed

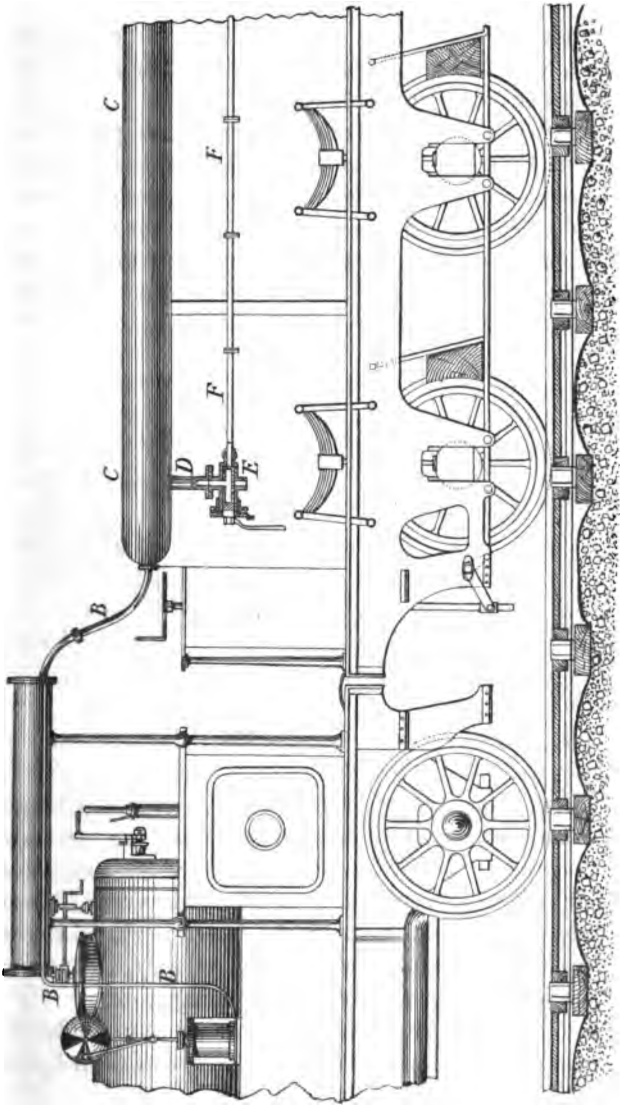
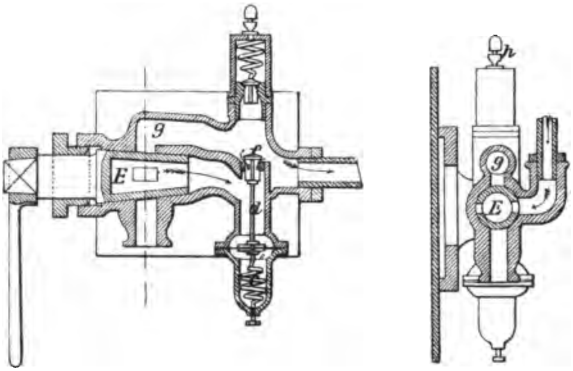


Fig. 14.—Steel and McInnes' Brake on a Locomotive and Tender.

through the tubing, F, to the cylinders or the carriages, or it may be entirely cut off therefrom, or directed into the atmosphere.

In order that there may be a uniform pressure of air in the pipes connecting the different brake-cylinders, and also that there may be a higher reserve air-pressure at the command of the operator of the two-way cock, E, it is preferred to attach to the two-way cock a reducing-valve, as shown in section at Figs. 15. The spiral spring, *c*, the strength of which is adjusted to the required air pressure, presses upon the lower end of the valve-spindle, *d*, which passes through and is attached to a flexible or elastic diaphragm, *e*, near its lower end, while its upper end is attached to a conical valve, *f*, the area of which is less than that of the diaphragm, *e*.

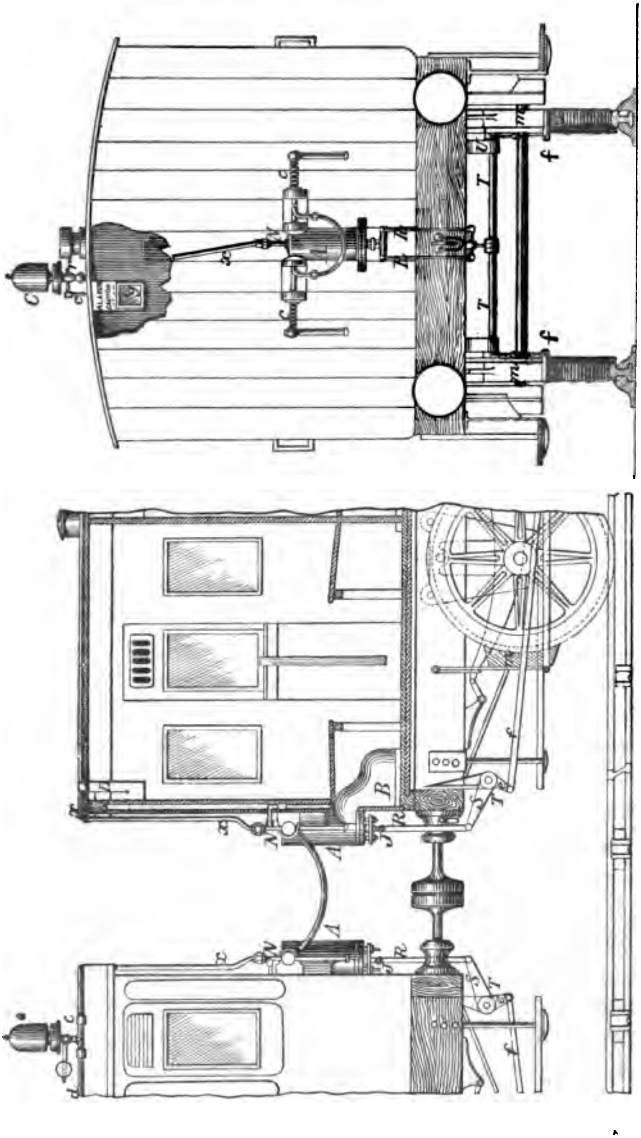


Figs. 15.—Steel and McInnes' Brake—Reducing Valve.

Air admitted from the receiver on the tender by the cock, E, enters the reducing valve, as shown by the arrows, and in passing through the valve, *f*, the air acts upon the diaphragm and the valve in such a way that as the pressure increases the area of opening at the valve, *f*, is diminished by virtue of the greater area of the diaphragm, *e*, and thus the pressure upon the efflux side is reduced.

When the cock, E, is turned on so as to allow the air to escape from the air-cylinder and tubes as described, and thus brake the train, the air does not return through the valve, *f*, but finds its way to the cock, E, through a side passage, *g*, provided for that purpose. A whistle, *h*, is placed above the valve, *f*, as shown, the valve of which whistle rises when the pressure beneath it is equal to the pressure in the receiver on the tender, so that should the reducing valve, *f*, become accidentally inactive, and allow an equal pressure of air above it, the whistle will sound, and thereby warn the driver of the inefficiency of the reducing valve.

Figs. 16 are side and end views of parts of a first-class railway carriage and a third-class carriage, coupled, showing the brake and whistle apparatus. The air-cylinders, A, A, at both ends of each carriage, are connected in their upper parts at the pipe, N, by the tube, *x*. Near one end of each carriage the whistle is situated on the roof. The means of working the whistle apparatus is shown more particularly at the section of the third-class carriage, end view. As shown by these figures, a box, D, is fixed on the side and near the roof of each compartment, the upper part of the front of the box is composed of wood, and the lower part of glass, as shown more particularly in the end view. A handle is suspended in the box, D, by a wire-cord or chain, which, passing over a pulley, is carried along the



Figs. 16.—Steel and McInnes' Brake.

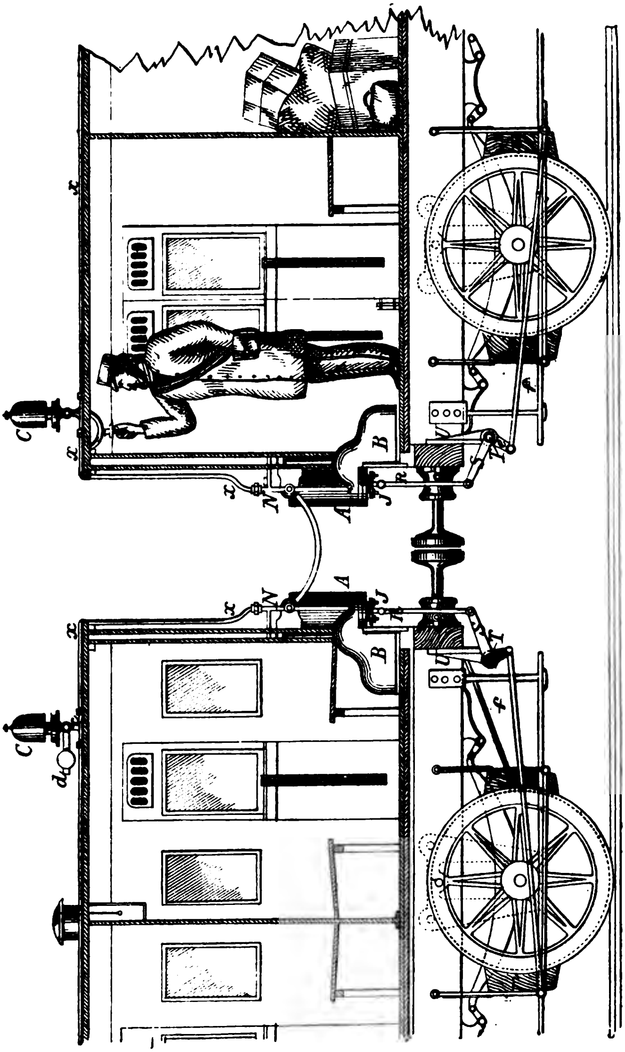


Fig. 17.—Steel and McInnes' Brake.

roof of the carriage, and attached to the lower extremity of the lever, *c*.

The lever *d*, standing at right angles to the lever *c*, carries a counter-weight which shuts the valve of the whistle, *c*, on the pulling strain being removed.

Fig. 17 shows, in part section, the front portion of a guard's van. The branch from the tube, *x*, is passed into the interior of the van, and is provided with a cock or valve, which is operated by the official or guard of the train in the manner shown. The brake-blocks are actuated from the piston-rods, J, through the connecting links, R, which actuate the levers, S, fixed upon the brake-shaft, T.

From the brake-shaft, T, the brakes, *m*, are operated in the ordinary manner by the levers, *e*, and connecting rods, *f*. The brake-shafts, T, are carried by bracks U, bolted to the lower framework of the carriage.

Figure 18 is partly a vertical section and partly a front elevation of a double-acting air force-pump, with steam engine attached, suitable for raising the necessary air-pressure in the receiver on the tender, and which may, of course, be fixed in any convenient part of the locomotive. Fig. 19 is a side elevation of the same, whilst Fig. 20 is a horizontal section of the air-pump barrels showing a plan of the valve-chests, which are also shown in section at Fig. 21. The air-pumps, A, are driven from above by the steam cylinders, C, which also actuate a double-crank shaft, B, by means of the connecting-rods, D. The air-suction branches on the valve-chest, G, and the respective pump-barrels are connected by a perforated tube, E, which it is preferred to use in order to prevent

Fig. 18.

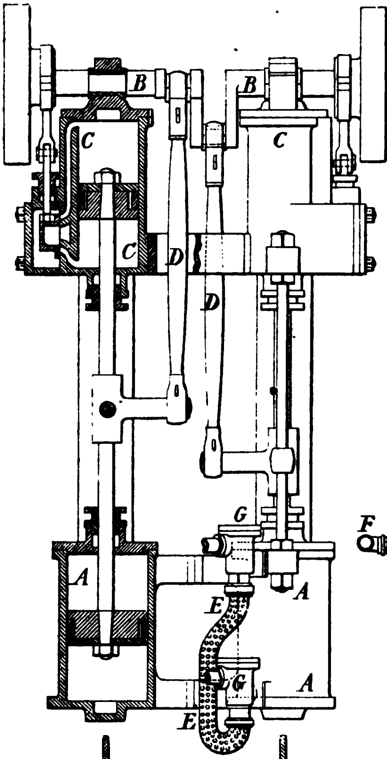
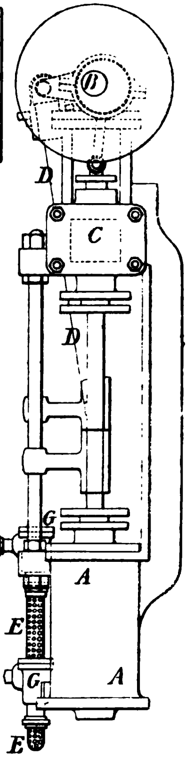


Fig. 19.



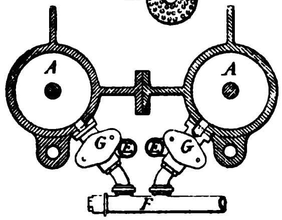


Fig. 20.

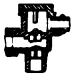


Fig. 21.

Steel and McInnes' Brake.

as much as possible the entrance of foreign substances into the valves of the pump.

Through the pipe, F, in Figs. 19 and 20, the air is pumped into the receiver on the tender.

The mode of working the apparatus is as follows:—A sufficient pressure of air having been raised in the receiver, C, by the air pump, A, the two-way cock, E, is opened, allowing the air to travel through the tubing into the air-cylinder on the first carriage, whence it issues through the pipes on the carriage roof to the air cylinder at the opposite end of the carriage, and thence similarly through the flexible pipes and couplings to the several other cylinders of the air-brake apparatus throughout the train. When it is desired to apply the brake, the air-pressure is removed from above the pistons, N, either by the engine-man turning the two-way cock on the engine so as to let "off" air above the pistons, or which may be accomplished by the guard turning the cock in the guard's van, or by a passenger pulling one of the alarm handles and letting the air escape to sound a whistle.

The air confined under pressure in the air-vessels, B, and under part of the cylinders A, when the pressure above the pistons is removed, expands and lifts the pistons, N, carrying with them the piston rods, J, and links, R, which actuate the levers, S, and through them the brake-shaft, T, which operation, as will be seen by reference to Fig. 17, apply the brakes by working the lever, *e*, and connecting rods, *f*.

To withdraw the brakes, the pressure of air is again exerted in the upper part of the cylinders, A, which throws the pistons, N, into equilibrium, when their own weight and the weight of their attachments, which may or may not be weighted, cause the pistons to fall to the bottom of the cylinders, A, and thus remove the brake-blocks from the wheels.

The coupling operation, whereby the air-cylinders on the adjoining carriages or vehicles, composing the train, are connected, is effected by placing the T-piece coupling, *f*, Fig. 12, page 57, between the inner extremity of the screws, *c*, and the face of the elastic rings, x, and screwing up the coupling firmly in this position by means of the vice-handles. The apparatus for fixing the T-piece coupling is placed on both sides of each cylinder, A, and each cylinder being provided with two flexible tubes and couplings, one or both of which may be used to connect the cylinders of adjoining carriages. When in action, the cylinders are coupled together by both flexible pipes, but in uncoupling them for the purpose of disconnecting the carriages, it is necessary to unscrew one coupling on each carriage and the opposite side of the respective cylinders, so that one of the flexible tubes is left hanging to each cylinder, thus allowing the flexible tubes and couplings always to come together in proper position for being coupled whether the same ends of the carriage are brought again opposite to each other or not. In the event of a rupture of one of the flexible tubes between the cylinders on adjoining carriages taking place, the coupling-hole in the cylinder may be closed by the thimble on the end of the coupling screw being pressed into it by the screw, and connection maintained by one pipe for working the brakes.

At the end of the last carriage of a train both of the couplings of one flexible pipe are applied to the opposite sides of the same air-cylinder, thus closing the openings and preventing the escape of air at the last cylinder; or, otherwise, the flexible pipes and couplings may be withdrawn, in which case the openings are closed by the thimbles on the ends of the screws *c*.

As the pressure of air is in constant action throughout the train, it may at any time be instantaneously applied, and in the event of the ordinary draw-bar, screw, or chain-coupling breaking, so that the train becomes disconnected whilst running, the air on the upper side of the pistons escapes through the broken air-pipes, the brakes are instantly applied, and the whole train is stopped.

Conclusion.—The Steel-McInnes brake, as described, has the great objection of using air pressure on both sides of the piston, and requiring, therefore, a stuffing-box, which will give rise to very serious trouble in practice. A stuffing-box may be kept tight on an engine and tender, where the driver and the fireman can look to it every day, to keep it tight; but when used on thousands of carriages, it would be found impossible to keep the stuffing-boxes in proper working order.

A second objection is the enormous amount of air used at each application of the brake. To apply the brake with full power, all the cylinders, with the brake-pipe, have to be emptied, however short the stroke of each of the pistons may be.

A third objection is the unavoidably slow action resulting from the fact that, at the engine, an enormous volume of air has to be discharged through a pipe of comparatively small diameter before the brakes are applied.

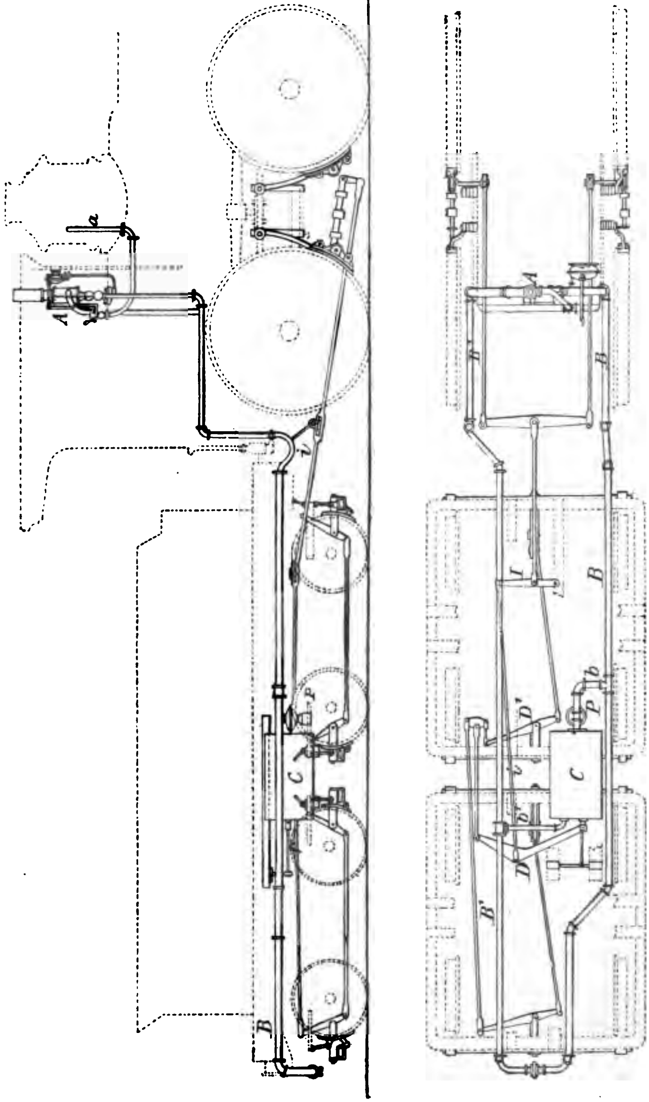
Owing to the foregoing objections, this brake has never been introduced largely into practical use, and has only been applied for experimental purposes.

CHAPTER IX.

EAMES' VACUUM CONTINUOUS-BRAKE.

THE working of this brake is accomplished by the natural pressure of the atmosphere, opposed to a vacuum. The vacuum is formed in a continuous pipe from end to end of a vehicle by means of an air-ejector, pump, or other exhausting apparatus, worked by the force of steam from the locomotive. The apparatus is shown in Figs. 22 as applied to a locomotive engine and tender. A represents an air-ejector worked by steam from the boiler, which is conducted through a suitable pipe, *a*. This ejector is employed to create a vacuum in the air-pipe, which extends throughout the length of the train, and is connected with the brake-cylinders attached to each carriage.

B, B′ are the air-pipes which are attached to the several carriages of the train, and are connected between the carriages by suitable flexible-hose couplings. The air-pipes are also connected by means of a branch pipe, *b*, with a brake-cylinder or vacuum-chamber, *c*, secured to each carriage. These brake-cylinders are fitted with pistons and piston-rods. A vacuum is maintained on both sides of the piston, to keep the brake-blocks off the wheels. By destroying the vacuum on one side of the piston, the brakes are



Figs. 22.—Eames' Vacuum Continuous-Brake.

immediately applied through the brake lever, D, which is connected with the piston-rod. To illustrate the operation of this brake, we will suppose the ejector, A, to be in operation, drawing air from the pipe, B, and cylinder, C. There being a valve in the piston-head, it will also draw air from the cylinder at both sides of the piston; and through the branch pipe, *p′*, it will also draw air from the pipe, B, creating a vacuum in both pipes and cylinders. The operation of the ejector being automatic, the vacuum will be preserved, and the brakes kept clear of the wheels until it is desired to apply them. To apply the brakes, the valves of the ejector are shifted so as to close communication between the pipe, B, and open it between B′ and the ejector. At the same time, another valve is opened to the pipe, B, to admit air into the pipe and destroy the vacuum. The air passes by the pipe, B, through the branch, *b*, into one of the cylinders, C, thereby moving the piston-rod. At the same time the ejector may continue its operation, and draw air from the other side of the cylinder through the pipe, B′, and *b′*, thereby aiding in applying the brakes quickly.

By again reversing the position of the valves of the ejector, communication is shut off between the pipe, B, and the external air, and opened between it and the ejector. The operation of the latter will then draw air from the pipe, B, and the cylinder, C, and create a vacuum therein to release the brakes.

The method of storing vacuum power by the use of an additional tank having free communication with the working cylinder, is shown in Fig. 23. In this, as in the other figure, C is the working cylinder; B, and B′, the air-pipes connected with the ejector A. B^1 is a branch pipe which connects the working cylinder, C, with an exhaust tank, C′, and also connects both of these vessels with the air-pipe, B′. The operation is

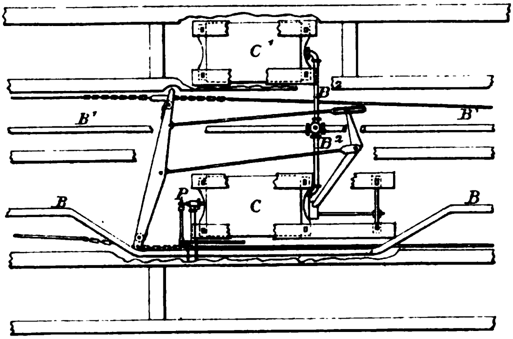


Fig. 23.—Eames' Vacuum-Brake—Storage Tank.

substantially the same as before described, the only difference being that when the ejector is withdrawing air from the pipe, B, it also withdraws it from the reservoir, C′, and thereby creates additional vacuum power.

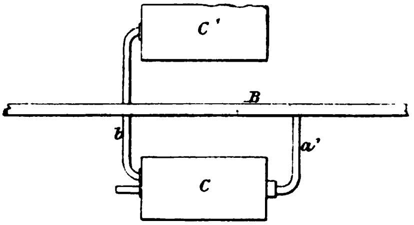


Fig. 24.—Eames' Vacuum-Brake—Storage Tank.

It will be seen that this apparatus has two lines of air-pipes; but, if preferred, a single pipe can be used as illustrated by the diagram, Fig 24, in which C is the working cylinder; C′, the exhaust tank; and B, the air-pipe, connected with the ejector apparatus and with the cylinder, C, by means of the branch pipe, *a*′; but not connected directly with the reservoir, C′, the reservoir being only connected with the end of the working cylinders, opposite to the pipe, *a*′, the connection between the cylinder and reservoir being by a small pipe, *b*. In this case, the air is withdrawn from the exhaust tank, C′, and from the cylinder, C, at the back of its piston through a valve in the piston.

Both arrangements are worked from the locomotive, and are under the control of the driver. The brakes can also be applied from any part of the train, by pulling open the valves communicating with the external air, the valves being attached to the several brake-cylinders as shown at P, in Figs. 22 and 23; suitable cords or levers being led to convenient positions in the carriage. By means of the lever on the tender and the connecting rod, *i*, the brakes of the locomotive are worked by means of the brake-cylinder and piston attached to the tender, no brake cylinders being required upon the engine. It will be seen on reference to Figs. 22, that the toggles for working the locomotive-brakes are arranged on the under side, or beneath the brake-shoes, so that, when released from the pressure of the levers, the brakes will drop loose from the wheels by their own gravity.

The brake-cylinders and connecting mechanism for working the brakes are shown to a larger scale in Fig. 25. A is the working vacuum or air-pipe which is connected with the engine and carriages throughout the train; and A′ is the re-force vacuum-pipe, which also connects with the locomotive and with the carriages throughout the train. *a* is a branch pipe leading from the pipe, A, to one end of the cylinder, B; and *a*′, a branch pipe leading from the pipe, A′, to the other end

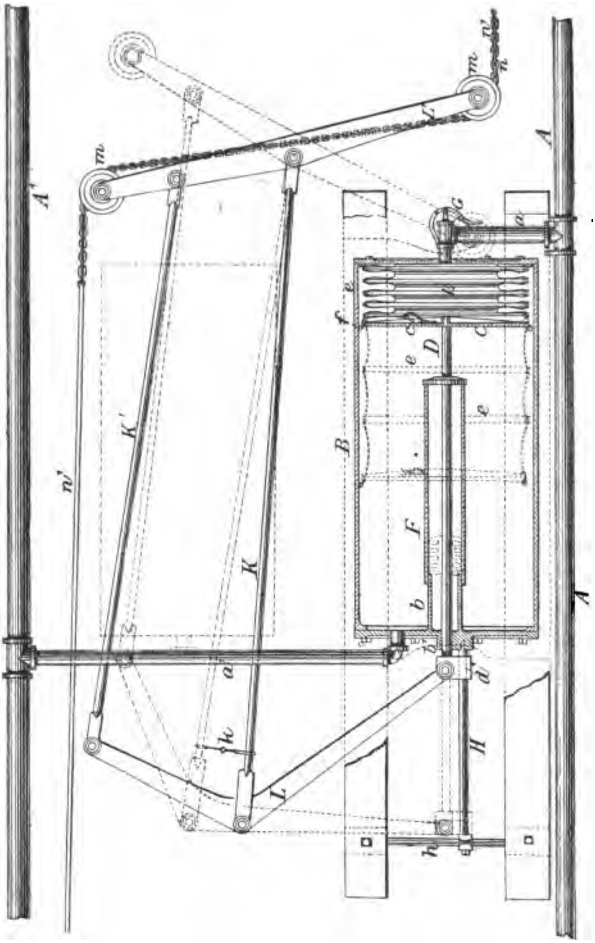


Fig. 25.—Eames' Vacuum-Brake—Brake Cylinder.

of the cylinder. C is the piston working in the cylinder, B, and D is the piston-rod; *c* is an opening through the piston-head, which is protected by an ordinary clack-valve, *c′*. E is an elastic compressible vessel or chamber, one end of which is secured to the piston, C, and the other to the head of the cylinder, B. This flexible chamber is made of indiarubber, and is braced at intervals, both inside and out, by means of metal bands, *e*. *f* are friction rolls secured or pivoted to the outer periphery of the piston at three or more points, the rolls working against the sides of the cylinder, and serving as guides to keep the flexible cylinder, E, in proper position.

F is another flexible chamber made of indiarubber, secured at one end to an annular and inwardly projecting flange, *b*, forming part of the cylinder, B; the other end of the elastic chamber, F, being secured to a disc, which is keyed to the piston-rod, D, so as to move with it. The branch pipe, *a*, opens into the flexible cylinder, E, so that when the air is withdrawn from the pipe, A, it is also withdrawn from the interior of the cylinder, B, the air passing through the openings, *c*, in the piston, so that a vacuum can be formed within the cylinder on both sides of the piston at the same time. The air passing in through the openings around the piston-rod at the other end of the cylinder will pass into the interior of the flexible chamber, F, and pressing on the head, *d*, will force the piston to move into the position shown by full lines in the drawing. While it is in this position, the brakes are released from the wheels, and the apparatus will so remain until the vacuum is destroyed in the pipe, A. When air is admitted to the pipe, it passes in through the branch, *a*, to the elastic cylinder, E, closes the valve, C′, and pushes the piston towards the other end of the cylinder, the elastic cylinder, E, expanding, and the chamber, F, contracting, until they reach the position indicated by dotted lines. When the apparatus is in this position, the brakes are applied. There is a valve in the branch pipe, *a*, having a port which communicates directly with the external air. This valve is provided with a lever, G, by means of which, and a connecting cord or rod leading to the interior of the carriage, the valve may be thrown open, and the air admitted to destroy the vacuum, applying the brakes from the carriage to which the brake-cylinder is attached.

By this means the brakes can be applied, and the train stopped from any part of the train by the passengers or by the guard, independently of the engine-driver.

It will be seen that the piston, C, does not travel the whole length of the cylinder, and therefore, as will be evident, the vacuum is only destroyed within a portion of the cylinder occupied by the flexible chamber, E. The other portion of the cylinder, therefore, forms a reserve reservoir or air-exhaust chamber, and, as before explained, the vacuum therein is reinforced by the continued withdrawal of the air through the reinforce vacuum-pipe, A′. By again withdrawing the air from the pipe, A′, the vacuum is restored on both sides of the piston, which then resumes the position first described, releasing the brakes.

H is a guide-rod, one end of which is secured to the cylinder head, and the other to a bracket, *h*; *d′* is a head upon the exterior end of the piston-rod; it is slotted to permit the guide-rod, H, to pass through it. *b′*, is a projection upon the cylinder-head, which acts as a stop to limit the inward motion of the piston in contact with the block, *d′*, on the end of the piston-rod; *i′* is a disc on the guide-rod, H, which also acts as a stop by coming in contact with the block, *d′*, thereby limiting the motion of the piston on its outward stroke. By thus limiting the motion of the piston, any strain or undue expansion of the flexible chambers E and F is prevented. *K*, *K′*, are vibrating rods, which connect the levers L and L′. *k* is a pendulous hanger which sustains the vibrating rod, K, or suspends it from the bottom of the carriage. The lever, L′, is provided with pulleys, *m*, on its ends, over which is passed the chain, *n*, connecting the brake-rods, *n′*. With this apparatus, it will be seen that the brakes are released by making a vacuum on both sides of the piston, and they are applied by destroying the vacuum on one side of the piston only.

Figs. 26 and 27 show respectively sectional and end views of another form of brake-cylinder, by which the brakes may be applied practically instantaneously. A represents the cylinder; B the piston; and C the piston-rod, the end of which projects through the cylinder, and connects with the brake-levers. D is a compressible sleeve, having a head, *d*, through which the piston-rod passes, and to which it is permanently secured, so that the joint is air-tight. The other end of the compressible chamber, D, is secured to the cylinder-head, also by an air-tight joint. The part of the cylinder-head immediately around the piston-rod, or within the area of the chamber, D, may be pierced with air-holes, *d′*. The piston has packing, C, of leather around its periphery, which is held by a ring, *c′*, all bolted together so as to form a perfectly air-tight joint, and prevent the passage of any air between the piston and the cylinder. E is an ordinary clack-valve, which covers an opening through the piston.. It is provided with suitable packing, and held in place by a spring, *e*. The cylinder-head is formed with two openings, A′ A″; the opening or port, A′, connects with a tube, G, which leads to and connects with the ejector on the engine, and with the vacuum-pipe throughout the train. The opening, A″, leads to the external atmosphere. H is a lever pivoted to the inner side of the cylinder-head. To the arm of this lever is jointed the stem of a valve, I, which covers the opening, A′. The stem, *k*, of the valve, K, projects into a small tube or chamber, L, secured to

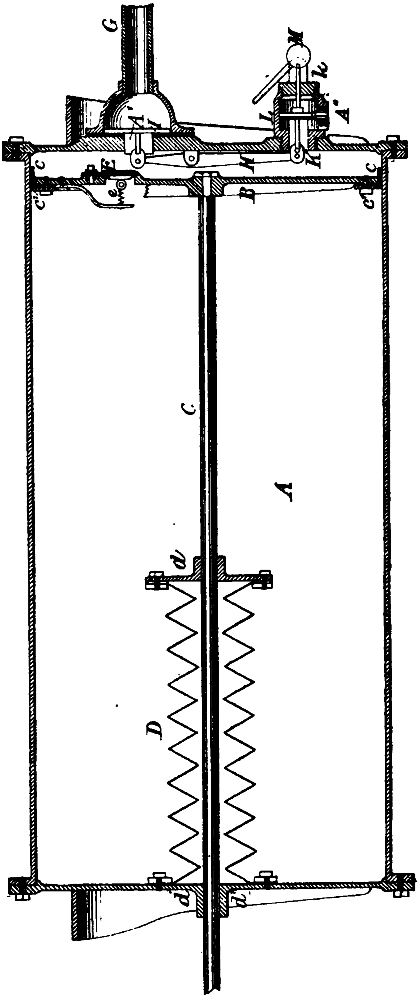


Fig. 26.—Eames' Vacuum-Brake—Brake-Cylinder.

the cylinder-head, and having an opening or openings leading to the external air. M, is an excentric arranged to come in contact with the valve-stem, and push in the valve to its seat, and hold it there when desired. A cap may be screwed on to keep the valve closed. The operation is the same in some respects as that of the brake-cylinder, Fig. 24. The air being withdrawn from the pipe, G, will cause the valve, I, to open and the valve, K, to close. The valve, E, will also open and permit of the air being withdrawn from the interior of the cylinder. As a vacuum is formed in the interior of the cylinder, air will enter within the compressible chamber, D, through the perforations around the piston-rod, and force the piston to the other end of the cylinder in the position shown by the drawing. So long as a vacuum is maintained in the pipe, G, the piston remains in this position; but as soon as the vacuum in the pipe is destroyed, the valve, I, instantly closes, thereby forcing the valve, K, open, and air passes immediately into the cylinder and forces the piston towards the other end, the chamber D, being compressed as the piston moves.

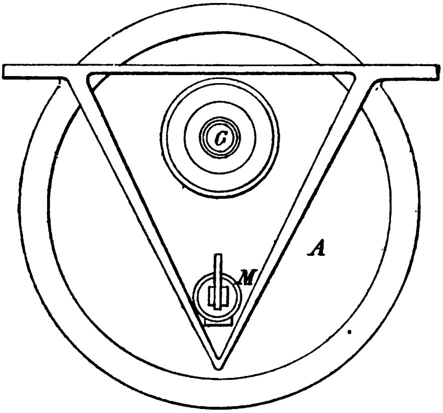


Fig. 27.—Eames' Vacuum-Brake—Brake-Cylinder.

Thus it will be seen that the destruction of the vacuum in the pipes alone is sufficient to cause the brakes to act, the vacuum in the cylinder being still preserved.

The piston does not require to move all the length of the cylinder in order to apply the brakes, so that the cylinder acts as a reservoir or exhausted receiver for storing vacuum-power; and a still greater capacity for storing this power may be had by simply connecting the cylinder with another receiver as indicated by dotted lines in Fig. 25. In this way, by means of the valves, K and I, the one working the other, the vacuum is instantly destroyed, and the brakes applied on the simple destruction of this vacuum in the pipe, G, without using up this reserved power in the cylinder. But should a more gradual application of the brakes be desired, the valve, K, may be kept closed, and the valve, I, open, by bringing pressure at M, on the stem of K, to force it down on its seat and hold it there, when the valve, I, will be held open, and the air to destroy the vacuum in the cylinder will pass in through the pipe, G.

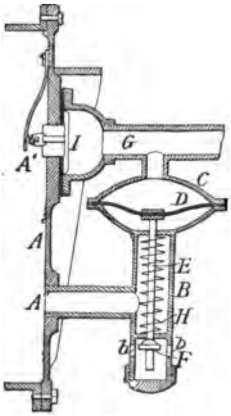


Fig. 28.—Eames' Vacuum-Brake—Automatic Valve.

Another form of the automatically acting valve for admitting air into the brake-cylinder to destroy the vacuum and apply the brake is shown in Fig. 28. This valve may be used in place of the valve shown at Figs. 26 and 27. A represents the head of the cylinder, having two openings, A′ and A″, the former connecting with the tube, G, which leads to and connects with the ejector on the engine, and the other, A″, connecting with a T-shaped branch pipe, B, fitted to a circular chamber, C, one end of which connects with the pipe, G. D is an elastic diaphragm secured within the chamber, C; and E is a valve-rod or stem, one end of which is secured to the diaphragm, D, and the other carries a valve, F. H is a spring, coiled around the valve-stem, E. *b b*, are openings or ports in the pipe, B, communicating with the outer air; I is an ordinary valve, which closes the opening, A′. The operation of this valve is as follows:—So long as the vacuum is maintained in the pipe, G, the diaphragm, D, will be drawn towards the pipe, thereby closing the port covered by the valve, F, and preventing the passage of air into the cylinder; but as soon as the vacuum is destroyed in the pipe, G, the spring, H, will retract the diaphragm and open the valve, F, and permit of the air passing into the cylinder to destroy the vacuum, the operation being very quick.

The steam air-ejector is shown in Figs. 29 and 30. A represents a steam-pipe, one end of which passes into the upper part of the boiler, and the other connects with the tube, C, which encircles the ejector-nozzle, B. D is the valve in the steam-pipe, A. The tube, C, is somewhat enlarged at its point of connection with the steam-pipe, A, but is drawn in at the nozzle of the ejector, and gradually decreases in diameter to a point some distance above the nozzle. It then gradually increases in diameter for about an equal distance: this part of the tube presenting the appearance of two united conical frustrums. The rest of the tube is cylindrical, and is cut or formed with slots or perforations, *c*, its top being solid or in the form of a cap.

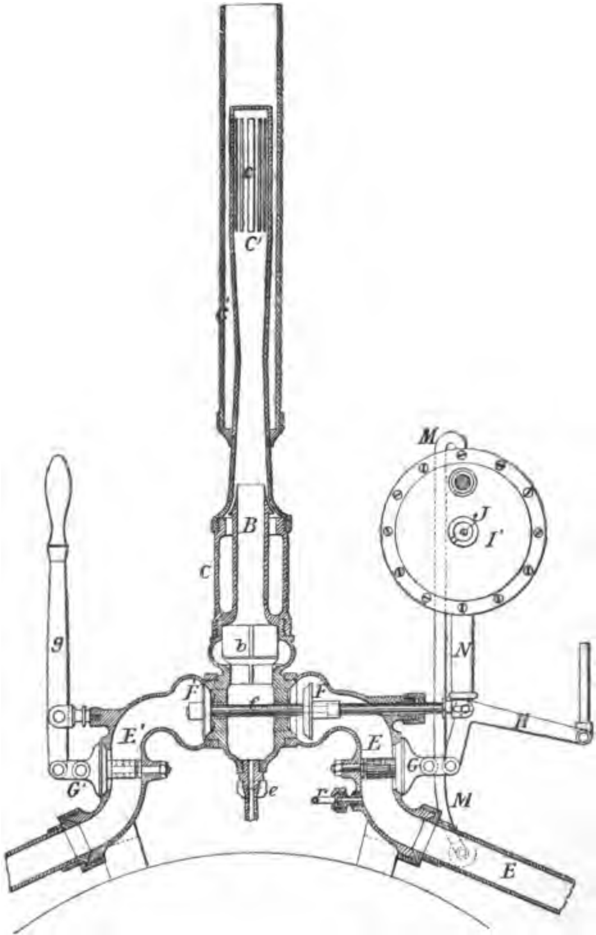


Fig. 29.—Eames' Vacuum-Brake—Steam Air-Ejector.

The upper portion of this tube, C, is surrounded by a jacket, C′, the upper end of which is open to the atmosphere. By making this eduction-pipe in this peculiar form very important results are obtained in the operation of the ejector. The air is drawn out more quickly and with less consumption of steam than many others, and the noise of the escaping steam is deadened so as to be hardly perceptible. B is the ejector-nozzle, and *b* a check-valve properly seated within the same. The lower part of this ejector connects with two branch air-pipes, E, E′, which connect with the air-pipes throughout the length of the train. *e* is a drip-cock in the lower end of the ejector, through which any water of condensation which may be found in it will pass away. F, F′ are two valves mounted on the same stem, *f*, and which serve to open and close commu-

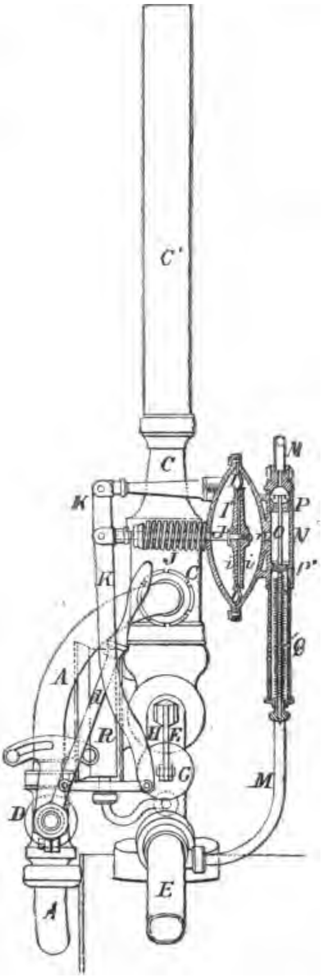


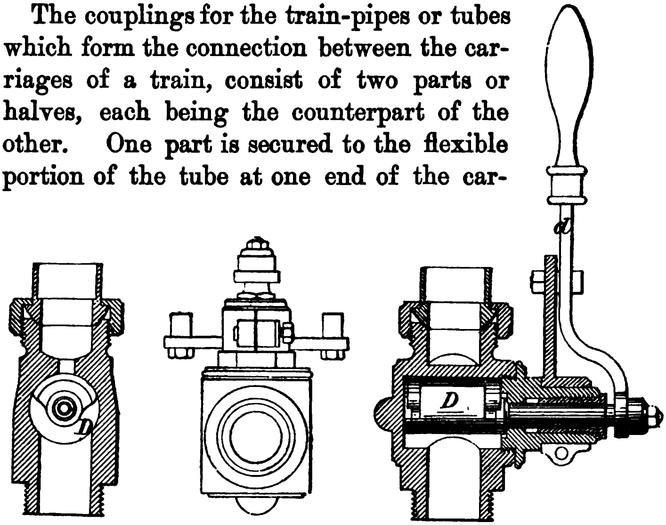
Fig. 30.—Eames' Vacuum-Brake—Steam Air-Ejector.

nication between the air-pipes, E, E′, and the ejector, B. G is a valve on the air-pipe, E, which opens outwardly to admit air into the pipe, to destroy the vacuum and apply the brakes when required. The valve-stem of the valves, F, F′ and G, are all connected together by means of a bell-crank lever, H, so that they all operate together. G′ is a valve on the air-pipe, E′, provided with a hand-lever, *g*. It also opens outwardly to admit air into the pipe, E′, but it is not used in connection with the automatic arrangement. It is intended for use in connection with the single pipe-brake. I represents a flexible diaphragm inclosed in a case, I′; this diaphragm is provided with suitable plates, *i*, *i*, and connected by means of a stem, J, with a lever, K, which has its fulcrum at K. The lower end of this lever, K, is pivoted to one end of a connecting-rod, L, and the end is pivoted to the hand-lever, *d*, of the steam-valve, D. *j* is a spring coiled around a piston-rod or stem, J. M is an air-pipe, one end of which connects with the train-pipe, E, and its other end connects with a valve-chamber, N, having an opening or port, *n*, leading into the diaphragm case, I′. O is a valve-stem located within the chamber, N, and which carries two valves, P, P′. The lower end of the valve-stem is also encircled by a coiled spring, Q.

The operation of the apparatus is as follows:—The brake-blocks are kept off the wheels by the maintenance of a vacuum in the air-pipes, E, E′. This vacuum is created and maintained by the suctional action of the steam from the boiler passing the pipe, A, and around the nozzle, B, drawing after it the air out of the pipes, the valve, *b*, rising to permit of its escape as soon as the steam is allowed to pass. So long as the vacuum is maintained in the pipe, E, it will also be maintained in the pipe, M, and through this pipe communicating with the case, I′, a vacuum will be formed in it on the adjacent side of the diaphragm, I, the effect being to draw the diaphragm towards the opening *n*, and through its connection with the stem, J, lever, K, and connecting-rod, operates to keep the steam-valve, D, closed. But, as soon as the vacuum in the pipe weakens, through leakage or other causes beyond a given degree, the spring, Q, will draw down the valve-stem, O, closing the valve, P, and opening the valve, P′, thereby destroying the vacuum in the case, I′, and allowing the spring, *j*, to move the stem or rod, J, and thereby, communicating with the lever, K, and rod,. open the steam-valve, D. The passage of the steam will again restore the vacuum in the pipes, and thus by the pulsation as it were of the diaphragm, I, the operation of the apparatus for the maintenance of the vacuum in the train-pipe is made automatic.

The steam-valve may be set so as to operate when the vacuum power is reduced to any given degree, and may be operated by hand when considered necessary. Thus, when it is desired to apply the brakes the engine-driver moves the lever, H, so as to open the valve, G, thereby admitting air into the pipe to destroy the vacuum, the brake mechanism being arranged so as to act on the destruction of the vacuum. By the same operation, the valve, F, is closed and the valve, F′, is opened, and the steam-valve being open the ejector will exhaust the air through the pipe, E′, thereby hastening the operation of applying the brakes and reinforcing the vacuum power as already explained. R is a vacuum-gauge connected with the pipe, E, by a small pipe, *r*, by means of which the amount of vacuum in the train-pipes can be ascertained. Figs. 31, 32, and 33 are detail views showing the construction of the steam-valve, D.

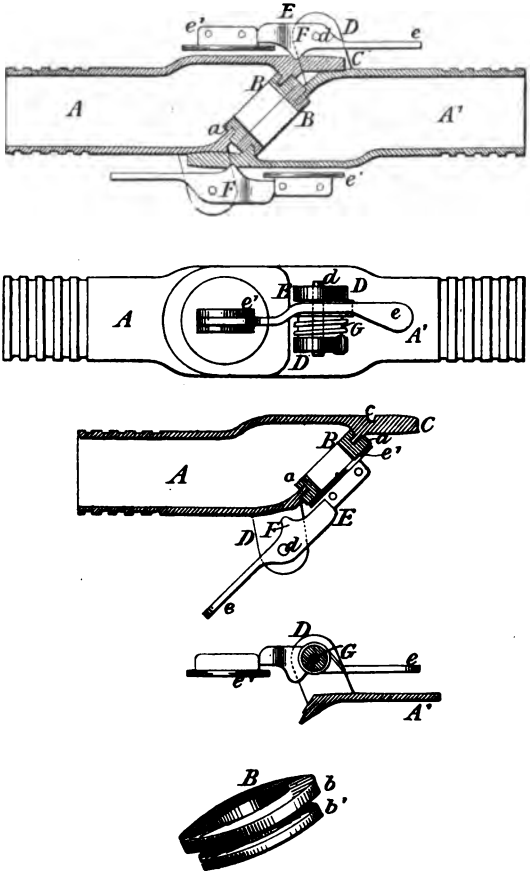
The couplings for the train-pipes or tubes which form the connection between the carriages of a train, consist of two parts or halves, each being the counterpart of the other. One part is secured to the flexible portion of the tube at one end of the carriage, the other to the tube at the other end, and they are so arranged that, when two carriages come together, one will present the right half, and the other the left half of the coupling, thus facilitating the coupling-up of two carriages. The necessity is thus avoided which might otherwise arise for twisting the flexible tube out of its proper position, in order to bring the parts of the coupling together.



Figs. 31, 32, and 33.—Eames' Vacuum-Brake—Steam-Valve.

Figs. 34 to 38 represent in detail a coupling which is particularly designed for use in connection with the

Eames brake. A, A′ are the two halves or parts of the coupling. As will be seen the opening in the outer end



Figs. 34 to 38.—Eames' Vacuum-Brake—Coupling.

of each half is in the form of an oblique cut. Around this opening an annular flange *a* is formed. B is a gasket of indiarubber formed with two annular flanges, *b*, *b′*, so as to leave an annular groove between them which, when the gasket is placed in position, is occupied by the annular flange, *a*. Each half of the coupling is also formed with a projecting lug, C, on the outer side of which, at some distance from the point, a transverse semicircular groove, *c*, is formed. D, D′ are lugs or lateral projections formed on the side of the coupling opposite to the lug, C. E is a lever which is pivoted between the lugs, D, by means of a pin, *d*, which passes laterally through the lugs. The outer end of the lever, E, is formed into a thumb-piece, *e*, and its inner edge is provided with a disc-valve, *e′*. On the inner side of the lever, E, is a projection of rounded form, corresponding to the form of the groove, *c*. G is a spring coiled round a sleeve, which encircles the pin, *d*, one end being secured to the lever, E, and the other to one of the lugs D.

When the pipes are to be coupled, all that is necessary is to take hold of the parts, one in each hand, press on the outer ends of the levers, E, thereby bringing them into position shown by Fig. 37, then push the two parts together until the gaskets, B, come in contact. The projecting lugs will then overlap, and the projection, F, will enter grooves, *c*, in which position the coupling will remain until the parts are again separated either by hand or by the accidental separation of the carriages. Should such an accident happen, the two parts of the coupling will separate without injuring the rounded projections, F, by means of which they are held together, slipping out of the grooves, *c*, *c′*. As soon as the parts are separated the springs, G, will force the discs, *e′*, against the gaskets, B, thereby instantly closing the openings of the ends of the coupling and preventing the passage of air into or from the train-tube. When the coupling is separated by hand, the result is the same, all that is necessary being to pull the coupling apart.

To sum up. The Eames brake has two brake-cylinders on the engine, two on the tender, and one on each of the vehicles. Two lines of pipe, with hose and couplings, extend throughout the train. One pipe, called the automatic-pipe, has a connection on each vehicle, with a valve-box, duplex-valve, which box has two other pipe connections, one with a reservoir, and the other with the brake-cylinder. The hose-couplings of the automatic-pipe have valves that can be held from closing by hooks, and are so held except when purposely closed, as at the rear of the train. The second pipe, called the plain-pipe, has a connection directly to each cylinder, and the hose-coupling between the carriages have valves that close when those couplings are not united. On the engine there are two ejectors, one, a small one, constantly working for creating and maintaining the vacuum in the automatic-pipe and reservoirs; and the other, a large one, for creating a vacuum in the plain or non-automatic-pipe when wanted. There are also valves for admitting the steam to the ejectors, and other valves to admit air to the two lines of pipe, as well as gauges to indicate the degree of vacuum in each pipe.

This brake is worked as follows:—The small ejector is started, and a partial vacuum is obtained in the automatic-pipe, valve-box, duplex-valve, and reservoirs. To apply the brakes for ordinary purposes, the large ejector is worked, and a partial vacuum is formed in the plain-pipe and all of the cylinders, a check-valve being put in each duplex valve-box to prevent air from passing to the cylinders from the automatic-pipe. The brakes are released by letting air into the plain-pipe and cylinders by means of a valve on the engine. If a train breaks in two, the two-pipe couplings separate. The automatic-pipe remains open, and destroys the vacuum in the pipe and on one side of the diaphragm in each valve-box, which diaphragm moves so as to open a passage from the reservoir to the cylinder, thus practically exhausting the air and applying the brakes. The brakes on the detached portion may be quickly released by simply opening the valve of the non-automatic or plain-pipe coupling which lets air into all the cylinders. Each van has a valve for admitting air to the automatic-pipe, for the guard to apply the brake. From the above it will be seen that the brakes are automatic if a train breaks in two, or if the automatic-pipe *alone* is destroyed. But the brakes will not act with effect if the flexible-piston of the brake-cylinder on any one carriage is destroyed, or if the non-automatic-pipe is broken off, as may be the case in an accident. The flexible pistons are of rubber and are exposed. They are therefore liable to be damaged.

Conclusion.—The Eames brake, with double line of pipe, although claiming to be automatic in its action, is subject to the same objections as non-automatic vacuum-brakes, because in many cases, as shown above, the brakes do not act, or they lose their power. This brake, therefore, does not give any more security than a non-automatic vacuum-brake, and the great complication of its component parts is entirely without object.

CHAPTER X.

ASPINALL'S AUTOMATIC VACUUM-BRAKE.

In the Aspinall brake, atmospheric pressure opposed to a vacuum is the force employed; the vacuum being formed by means of an ejector, or a pump.

A vacuum is maintained on both sides of a diaphragm-piston, by the action of exhaust. When the vacuum is destroyed on one side of the diaphragm, the brakes are applied. When the brakes are to be released, the vacuum is restored on both sides.

Fig. 39 is a transverse section of the apparatus as fitted to each vehicle of a train with a double-pipe system; *h* is the diaphragm which is inclosed in the air-tight casing *k*, and the rod from the diaphragm, *h*, works air-tight through the bottom of the casing.

The upper and lower parts of the cylinder, *k*, are united by flange-joints to which the leather of the diaphragm, *h*, is also united, as shown in the usual manner. Fig. 40 shows a modification of the brake-cylinder, in which the upper part of the cylinder is so much larger than the lower part, that, when a vacuum is produced in it, it practically acts as a vacuum reservoir upon the application of the brakes and so obviates the necessity of employing separate reservoir chambers, as is often the practice. Although such separate vacuum reservoirs may be employed with this form of cylinder, where a still greater power and rapidity of action is desired, the stroke or lift of the diaphragm, *h*, is limited, and thereby the durability of the leather ensured by the flange or ledge *k′*. The same object is attained in the cylinder shown in Fig. 39, by making the height of the upper part corresponding to the desired stroke or lift of the diaphragm. The height or capacity of the upper part of the cylinder shown in Fig. 40 should, where possible, be, say three times that of the lower part, because, for ordinary practical working purposes, a vacuum of 20 inches only is as much as can be obtained and maintained.

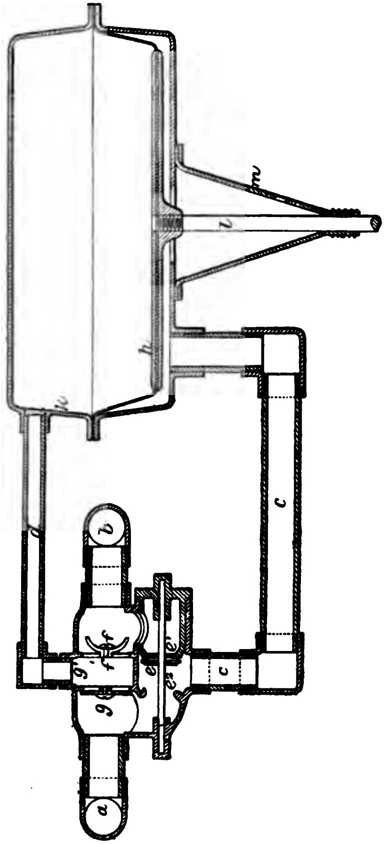


Fig. 39.—Aspinall's Brake.

The rod, *l*, for working the brake-gear, is attached to the diaphragm *h*, but works air-tight through the bottom of the cylinder, *k*, by an arrangement constituting a flexible or collapsible joint. The joint, which acts in place of an air-tight collar or stuffing-box, is formed by attaching to the outside of the casing a conical tube or sleeve, *m*, made of indiarubber or leather. This tube, *m*, is at one end fixed to the rod, *l*, and at the other to the bottom of the cylinder, *k*. It entails very little resistance or friction, and is durable and convenient.

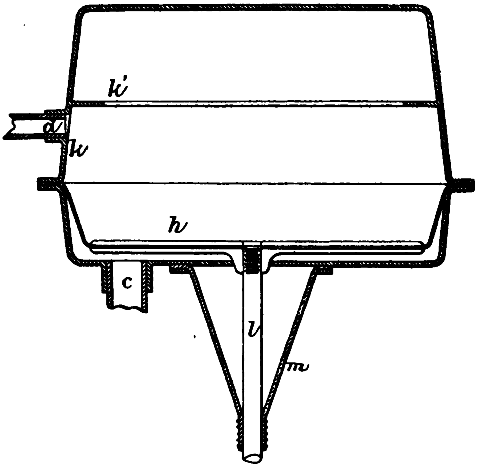


Fig. 40.—Aspinall's Vacuum-Brake—Modification of Brake-Cylinder.

Referring again to Fig. 39, *a* and *b* are two pipes which lead through the train, connected with the cylinder, *k*, on each side of the diaphragm, *h*, through a reversing double-beat and double-seat valve appliance, consisting of the two seats, e' and e^2, with the valve *e*, which can seat itself on either of them, and the valve seats f' and g', with the indiarubber valves, *f* and *g*, respectively. The pipe, *c*, communicates with the bottom of the diaphragm piston, *h*, and the pipe, *d*, with the top of the same. The consequence of this valve arrangement is that, if both train-pipes, *a*, *b*, are exhausted, the cylinder, *k*, will be exhausted on both sides of the diaphragm, *h*, because the valves, *g* and *f*, will open, and the valve, *e*, will be in a position between the two seats, e' and e^2; whereas, if air be admitted to either pipe, *a* or *b*, while the exhaust is continued through the other, the air will be directed to the bottom of the diaphragm, *h*, and allow the exhaust to be continued from the top. If, for instance, air be admitted to the pipe, *a*, the valve, *g*, will close on its seat, g', and the valve, *e*, will be driven over against its seat, e', as shown in the drawing—allowing the air from the pipe, *a*, to rush into the pipe, *c*, and to the bottom of the diaphragm, *h*. The exhaust at the same time continues through the train-pipe, *b*, and the pipe, *d*, the valve, *f*, remaining open, and a vacuum being maintained above the diaphragm, *h*, whereby the valve, *e*, is also retained firmly on its seat, e'. If air be admitted to both train-pipes, *a* and *b*, as, for instance, by the parting of the train, the valves, *f* and *g*, closing on their respective seats, shut off all communication with the pipe, *d*, and the top of the diaphragm, *h*, and the air flowing past the valve-seat, e' or e^2, or both, will be directed to the pipe, *c*, and the bottom of the diaphragm, *h*, raising the same against the vacuum above, and thereby applying the brake.

To allow the air admitted to one of the pipes, *a* or *b*, by the driver, when applying the brakes, to take full effect, a valve on a rod connected to a diaphragm is used on the engine to stop the communication between the pipe and the ejector when air is admitted. This arrangement is illustrated in Fig. 41; *i* is the diaphragm, and *j* the valve connected to it. This valve opens, that is, comes into the position shown, when the exhaust or larger ejector is started to set the brakes, or to release them, and will remain open so long as the vacuum is being maintained in both pipes, *a* and *b*. But it closes when air from any cause is admitted to the automatic-pipes, *a* and *c*, or *b* and *c*.

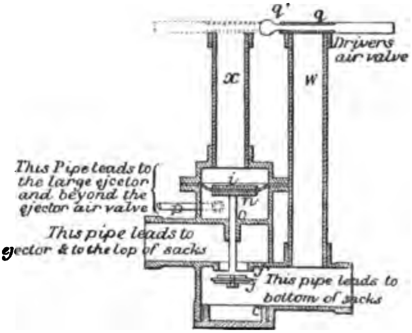

q'
q
Drivers air valve
x
w
This Pipe leads to the large ejector and beyond the ejector air valve
i
n
p
o
This pipe leads to ejector & to the top of sacks
j'
j
This pipe leads to bottom of sacks
c

Fig. 41.—Aspinall's Brake—Stop-Valve.

The mode in which this valve, Fig. 41, works, is as follows: *d* is a pipe leading to the ejector or pump, and to the upper portion of the cylinder, *k*; *c* is a pipe leading to the lower portion of the cylinder, *k*; *w* is a pipe in communication with *c*, but closed to the atmosphere by a moveable valve, *q*, which can seat itself either on the mouth of the pipe, *x*, or the pipe, *w*, turning on a hinge, *q'*. This pipe, *x*, admits atmospheric air to the top of the diaphragm, *i*, through which a very small hole, *n*, leads to a chamber, *o*, from which a small pipe, *p*, is led to the ejector above the valve usually placed in the base, so that, when the large ejector is not exhausting, the air is free to flow into the pipe, *p*, and chamber, *o*. The diaphragm is by a stem connected to the valve, *j*, which can close on its seat, *j'*, and stop communication between the pipes, *d* and *c*. So long as the exhaust is maintained in the pipes *d* and *c*, the valve, *j*, will remain open, as shown in the figure, but when the driver applies his brake, admitting air to the pipes, *w* and *c*, thence to the bottom of the cylinder, *k*, he turns the flap-valve, *q*, over on to the pipe *x*, and the valve, *j*, will close on its seat, *j′*, because there is a vacuum in the pipe, *d*. All communication between the pipes, *d* and *c*, is thus shut off, and the exhaust can be continued from the top of the cylinder, *k*. The large ejector having been brought into use in order to produce a greater vacuum above the sack diaphragm, *h*, Fig. 39, in order to intensify the action of the brakes, a vacuum is also created above and below the small diaphragm, *i*, Fig. 41, through the pipe, *p* and the small hole, *n*. The diaphragm, *i*, therefore, remains in equilibrium, and does not move the valve, *j*.

To release the brakes, the driver moves the valve, *q*, from its seat on *x* to its seat on *w*, thereby allowing the atmosphere to enter *x*, and preventing it from entering *w*.

The larger ejector can be started at the same time, creating a vacuum in the chamber, *o*. The air now acts on the top of the diaphragm, *i*, which is larger than the valve, *j*, and opens it instantly, and the air once more flows from the pipe *c* to the pipe *d*, and out through the ejector. The valve is also of great use in allowing the driver to graduate or regulate the power, or the suddenness with which the brakes are to be applied according to requirements.

In case air be admitted to either or both train-pipes from some part of the train behind the tender, a double-beat valve is used connecting the pipes, *d* and *c*, on the tender. This valve is illustrated by Fig. 42. It is placed in some convenient part of the tender, and is so arranged that the air will be directed to the pipe or chamber *c*, communicating with the bottom of the sack, *k*, on the tender, and connected to the diaphragm-valve above described with reference to Fig. 41, and which communicates with the bottom of the sacks on the engine and tender. The valve, Fig. 42, at the same time stops the admission of air to the other train-pipe on the engine and tender, so that the exhaust may be continued from the top of these diaphragms, *h*. It is constructed so that if air is admitted to the train-pipe, *a*, the valve, *r*, which is connected by a stem, r^2, with the valve, *s*, is forced on its seat, shutting off communication with the atmosphere and with the top of the engine-and-tender sack, and at the same time forcing the valve, *s*, from its seat, *s*′, and allowing the air to flow past *s* through the pipe, *c*, to the bottom of the engine-and-tender vacuum-cylinder.

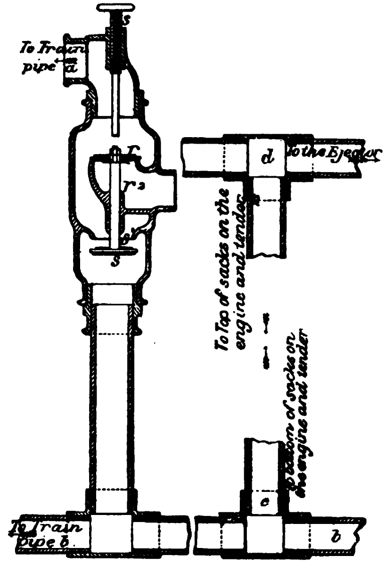

s
To Train pipe a
r
r²
s¹
s
d
To the Ejector
To Top of sacks on the engine and tender
To bottom of sacks on the engine and tender
e
To Train pipe b
b

Fig. 42.—Aspinall's Vacuum-Brake—Double-Beat Valve.

If, however, the air is admitted to the pipe *b*, and not to the pipe *a*, the valve, *s*, closes on its seat, s^1, and effects the same result. It is fitted with a screw, *s*, which is used when the engine is working a train fitted with the ordinary vacuum-brake. This screw serves to force the valve, *r*, on to its seat, so as to make the communication between the ejector and the top of the engine sacks, *k*, independently of the pipes between the train-sacks. Or, instead of the diaphragm-valve described with reference to Fig. 41, a single valve, *j*, as illustrated by Fig. 43, can be used in connection with an air-admission valve, *q*, whereby the driver, in admitting air to apply the brake, also shuts off the communication with the ejector, as indicated in the drawing. But where automatic action is required in all cases, a valve as shown by Fig. 42 is necessary.

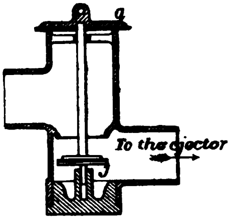


Fig. 43.—Aspinall's Vacuum-Brake — Single Valve.

When the engine is coupled with the train, the brakes are released by re-creating a vacuum in the lower portion of the brake-cylinder, *k*. This is done by dropping the valve of Fig. 43 (when this valve is used instead of that shown at Fig. 41) into its normal position here shown, when the injector will again exhaust from the train-pipe, *b*, and the lower portion of cylinders, *k*.

The brake as described above, with a double line of train-pipes, may be so adapted as to work at will as follows: air is allowed access to both sides of the diaphragm, *h*, and the brakes are applied by creating a vacuum one side of this diaphragm; the brakes are released by readmitting air and destroying the vacuum, or, in other words, the systems of vacuum-brake can be worked by the same arrangement. Carriages fitted with this brake can be interchanged with those fitted with other systems of vacuum-brake, which are likewise operated by double or single line of pipe, and which are fitted with similar couplings. The arrangement is the same as first described, with the following additions: the reversing valve, *g*, *e*, *f*, described with reference to Fig. 39, is used, and between it and the casing in the pipes, *d* and *c*, communicating with the top and bottom of the diaphragm, *h*, are respectively two valves. One is made to close the pipe in which it is placed when air is admitted to that pipe, which the reversing valve, *g*, *e*, *f*, will not now do when the train parts, and the other, or second valve, is so arranged that it can be set to open a through communication between the reversing valve and the bottom of the diaphragm, *h*, or close to the pipe from the reversing-valve, and admit air direct to the bottom of the diaphragm. When working automatically, this valve is in its first-mentioned position, and the first-named valve is free. When it is desired to work on the ordinary vacuum system, the second valve is fixed in its second position, and this at the same time fixes the first valve open. One of the arrangements for enabling the trains to be worked on either the automatic principle or the ordinary vacuum principle, is illustrated by Fig. 44, which is an arrangement similar to the one shown in Fig. 39, but with the addition of a three-way cock, and other parts. This figure simply shows another form of brake-cylinder, suitable where height is of importance. When working automatically, the plug, *u*, of the cock is so set, as shown, as to cause communication between the pipe, *c*, and the lower portion of the brake-cylinder, *k*, the consequence being that the opening through the cock to the atmosphere is closed. When working with Smith's or Hardy's system, the plug, *u*, of the cock is so set as to open communication between the atmosphere and the lower

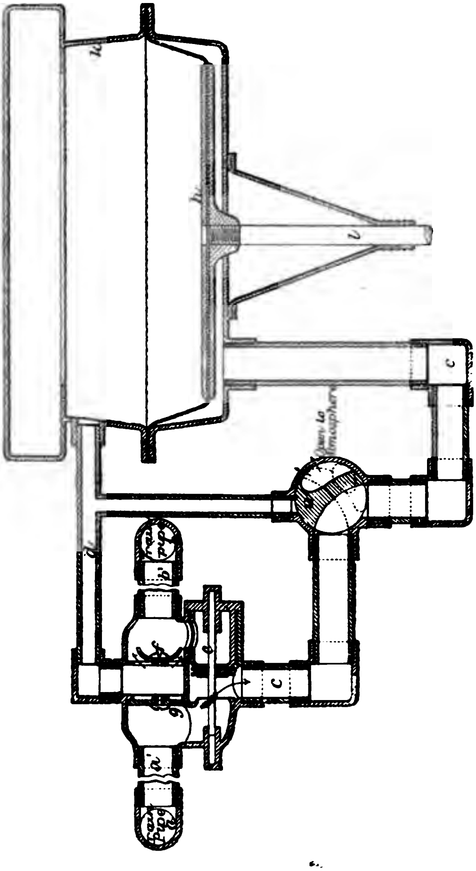


Fig. 44.—Aspinall's Brake—Alternative System.

portion of the brake-cylinder, *k*, also between the pipe *c* and the pipe *d*, leading to the top of the brake-cylinder, *k*, as shown in dotted lines; whereby is established a continuous communication between the lower

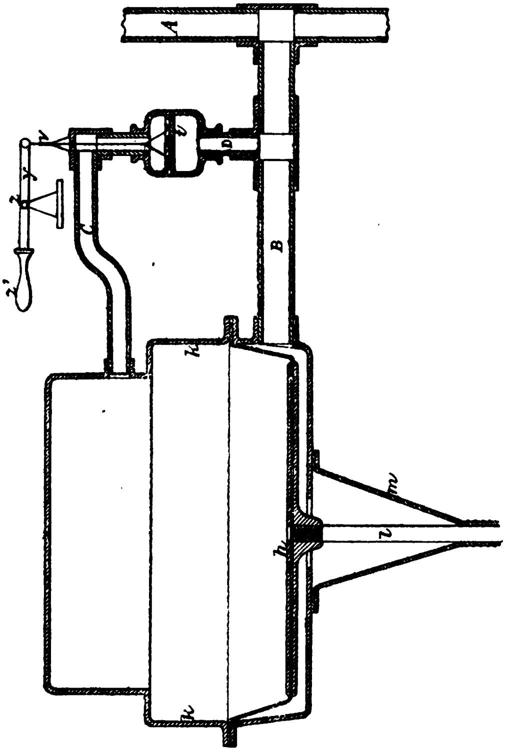


Fig. 45.—Aspinall's Brake—Single-pipe System.

portion of the cylinder, *k*, and the atmosphere, under all circumstances between the top part of cylinder, *k*, and the train-pipe, independently of the directing valves, *g*, *f*, *e*.

When working with the ordinary vacuum system, the screw *s*, Fig. 42, in the valve behind the tender is screwed up against the valve, *r*, forcing it against its seat. The driver's valve is also used with this system.

The mechanism employed with the single-pipe system is as follows:—Fig. 45 shows the brake cylinder applied to a single train-pipe, A, which, by a branch pipe, B, is connected with the bottom of the cylinder, *k*, and by a pipe, D, with the pipe, *c*, leading to the top of the cylinder, *k*. There is a valve between the two latter pipes, free to open when there is air in the upper and lower parts of the cylinder, *k*.

When air is admitted to the train-pipe, A, the diaphragm, *h*, will be forced up and the brakes applied, the valves at the same time closing, and retaining the vacuum in the upper portion of the casing, *k*.

To take off the brakes, a vacuum must be recreated in the train-pipe, A, or air must be admitted to the upper part of the cylinder, *k*, if the engine is uncoupled from the train. This latter is effected by opening the valve, *t*, by means of the rod, *v*, which, as it passes out through a hole in the pipe, *c*, is provided with a flexible sleeve or tube joint, similar to that of the rod, *l*, at the bottom of the cylinder, *k*. By means of a lever, *y*, on a weigh-shaft, *z*, and the lever-handle, *z′*, the valve, *t*, may be opened from each side of the carriage. The handles, *z′*, are so heavy as to keep the rod, *v*, normally in the raised position here shown.

Improvements have been introduced for regulating the flow of air in vacuum-brakes, so that as soon as the vacuum in the train-pipe for automatic action is seriously impaired, the brake flies on at once and pulls the train up. The improvement relates to valves. Fig. 46 is a vertical section through one of these valves; it consists of a head or plate, *a*, fixed to a flexible diaphragm, *b*, above which there is a close chamber, *c*; this diaphragm-head, *a*, or a continuation thereof, in the form of a valve, *a′*, as shown, in this instance seats itself in the lowest position of the diaphragm, *b*, on a valve seating, a^2, and closes the communication between the train-pipe, *c*, and one or more—in this case four—apertures, *d*, to the atmosphere.

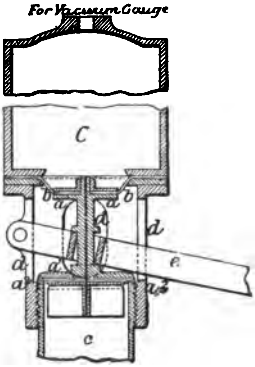


Fig. 46.—Aspinall's Brake. Valve.

There is a communication hole through the stem of the valve, *a a′*, or a very small pipe establishing a certain degree of communication between the chamber, *c*, above the diaphragm and the under side of valve. The lever, *e*, for actuating this valve by hand is so balanced relatively thereto that, when a vacuum is created throughout the train-pipe, *c*, and by the small communicating hole in the chamber, c, above the diaphragm, the valve, *a a′*, is almost in equilibrium; but as the head, *a′*, is greater in area than the diaphragm head, *b*, it remains sufficiently tight in its seat, a^2, to prevent air admission to the train-pipe, c. When the vacuum in the latter is impaired, the equilibrium is destroyed. The atmosphere, having, as before, access to the underside of the diaphragm, *b*, will then force the latter up, raising the valve, *a′*, from its seating, a^2, and admit air completely to the train-pipe, *c*, at this place by the opening, *d*. Atmospheric air will now gradually find its way into the chamber, c, above the diaphragm through the small hole; the valve *a*, *a′*, will then descend again by gravity and close the air admission to the train-pipe, *c*. By means of a vacuum-gauge connected to the chamber, c, the brake-power may be constantly indicated. This improved valve is applicable to the single-pipe system and the double-pipe system already described. In the latter case, it is connected with the pipe communication with the lower portion of brake-cylinder under the guard's van, an ingenious valve device for automatic action where double lines of pipes are used along the train.

In case air is admitted to either or both pipes from any part of the train the air will be directed to the lower part of the sack, and the vacuum upon the upper side of the sack diaphragm will be maintained, or the exhaust may be continued from the upper part of the diaphragm where only the pipe is severed; or air is admitted by the driver or the guard, or by accident, to the lower side of the sack.

Fig. 47 is a cross section of one such directing valve. It has four valve-seats, e^2, f^2, g^2, h^2, meeting in one centre line, and arranged in a casing which, at two opposite sides, viz., at *a′* and at *b′*, communicate respectively with two main pipes; and at two other sides, viz., at *d′* and *c′* respectively, with top and bottom of sacks. The valve is made of one continuous piece of leather, having three metallic pieces to stiffen it.

By this valve arrangement, which is placed between the two train-pipes, the flow of air is automatically regulated from the top and bottom of the sacks.

Fig. 48 is a section of a directing valve to be used on the engine for the purpose of putting on and releasing the brakes. This valve is used in combination with the valve shown in section in Fig. 49. This valve regulates the flow of air to the bottom of the engine-and-tender sacks. By the combination of these two valves (Figs. 48 and 49) the use of the engine-man's valve and the valve at the back of the tender, already described, may be dispensed with.

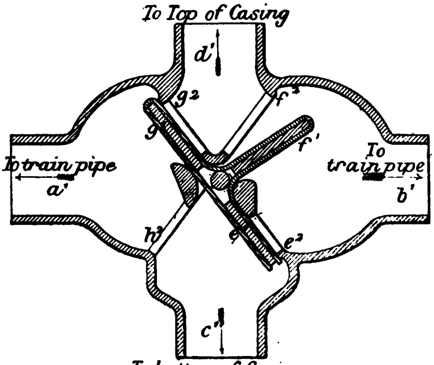


Fig. 47.—Aspinall's Brake—Directing Valve.

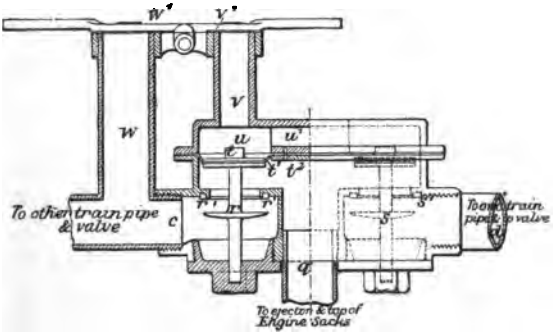

w'
v'
v
w
u
u'
t
t'
t2
r'
r
r'
s'
s
To other train pipe & valve
c
To other train pipe & valve
q
To ejector & top of Engine Sacks

Fig. 48.—Aspinall's Brake—Directing Valve.

The valve, Fig. 48, is constructed in two parts, which are similar to one another. The pipe, *q*, leads to the ejector and to the top of the engine-and-tender sack. The ejector exhausts the air from the train-pipes, *c* and *d*, which flows past the valves, *r* and *s*, to the pipe, *q*. The valve *r* is formed with a spindle having two heads, the head, *r*, seats itself on the seat, *r′*, and shuts off communication between the pipe, *c*, and the ejector pipe, *q*. The head, *t*, is attached by means of a diaphragm, *t′*, to the flange of a chamber, *u*, which communicates with a similar chamber over the valve-spindle of *s*, by means of the opening, *u′*. There is a small hole, t^2, causing communication between the pipe *q*, and the passage, *u′*. A pipe, *v*, upon the top of which is a flap valve, *v′*, communicates with the chamber, *u*. The pipe, *w*, communicates with the train-pipe, *c*, and terminates with a flap valve, *w′*.

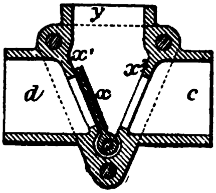


Fig. 49. — Aspinall's Brake—Regulating Valve.

To apply the brakes, the driver lifts *w′*, air flows to *c*, and forces *r* into its seat, *r′*. A vacuum has been formed above the head, *t*, through the small hole, t^2; *t* is therefore in equilibrium. The ejector goes on exhausting through the train-pipe, *d*, as the valve, *s*, remains in the position shown in the drawing. To take off the brakes, the driver closes the valve *w′*, and opens the valve *v′*. Air now rushes to the top of the head *t*, and this being larger in diameter than the head *r*, it forces it on to its seat, *r′*, and the air in the train-pipes, *c*, once more flows to the ejector. As soon as the brakes are off, the valve *v′* may be dropped on its seat, when the head, *t*, will once more be put in equilibrium by the air being drawn out of the chamber, *u*, through the hole, t^2.

Should air be admitted by accident to the train-pipe, *d*, the valve, *s*, will act in a precisely similar manner, and may be reopened by opening the valve, v'. Should air be admitted to both train-pipes by accident or otherwise, both valves, *r* and *s*, will close, the brakes on the engine and train will be applied, and the ejector will continue to exhaust from the top of the engine and tender, and the brakes will be released by opening the valve v'. The valve shown in section at Fig. 49 is placed between the train-pipes, *c* and *d*, upon the engine, and directs the flow of air to the bottom of engine-and-tender sacks. The pipes *c* and *d* are not connected with the top of the engine-and-tender sacks, but only with the bottom of them through the valve. This valve, *x*, is formed with two seats, x' and x^2. It has three branch-pipes, of which *c* and *d* communicate with the main train-pipes; the third branch, *y*, leads to the bottom of the sack. If air is admitted to *c*, the valve *x* flies over to its seat, x', as the ejector continues to exhaust through the pipe, *d*. If air is admitted to *d*, the valve *x* seats itself on x^2, and the ejector continues to exhaust through the pipe *c*. In either of the above cases, the air flows to the bottom of the engine-and-tender sack, through the branch, *y*, and the brakes are applied. If air is admitted to both *c* and *d*, it flows to the bottom of the sacks through *y*, and applies the brakes.

A valve is made for the purpose of closing the connection between the upper portion of the sacks and the train-pipe, at the same time ensuring that the same shall be reopened either by the creation of a vacuum in the train-pipe equal to or less than that in the upper portion of the sacks, or by hand where it becomes necessary. This valve is used either with the single or the double-pipe system to enable communication between the ejector and the top of the sacks to be established after the brake has been applied, and after the power of producing as good a vacuum in the train-pipes as there is in the top part of the sack, has been lost. The valve, which is shown in section in Fig. 50, will, when seated on the seat, *l*, close the connection between the train-pipe and the top of the sacks. It is formed with a hollow stem, *m*, communicating by one or more perforations with the train-pipe (and thus also with the bottom of the sacks), and passes air-tight through the wall of the valve-chamber. Being attached thereto by a leather sleeve or tube, *m′*, its outer open end terminates in a chamber, *n*, one side of which is formed by a head, *h*, on the stem of the valve, the head being attached to the sides of the valve-chamber by a diaphragm, *g*. The head, *h*, is fixed to the hollow stem, *m*, by means of the nut, *f*. The stem may be solid, and a side passage be formed between the chamber and the communication to the train-pipe.

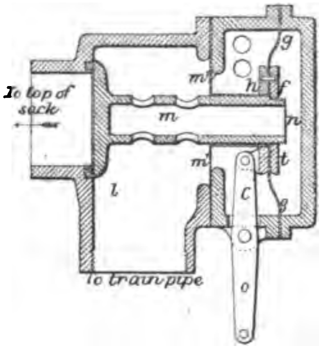


Fig. 50.—Aspinall's Brake—Valve.

Conclusion.—The Aspinall Brake in its various forms, as described above, has only been partially applied for experimental purposes, and cannot be considered to have entered into practical working.

As far as the single-pipe brake is concerned, it is subject to most of the objections raised against the Hardy Automatic Vacuum-Brake, whilst the double-pipe arrangement has the same defects as the Eames apparatus, and is, therefore, not much safer than a non-automatic brake.

CHAPTER XI.

BARKER'S HYDRAULIC CONTINUOUS-BRAKE.

HYDRAULIC brakes are worked by means of salt-water or other liquid stored under pressure in an accumulator. To pump the liquid into an accumulator, Barker employs a direct-acting steam-pump, which can be worked by steam from the boiler of the locomotive, and is constructed in the following manner:—The steam-cylinder and the pump-cylinder are, as usual in direct-acting steam-pumps, in a line with each other, tandem fashion, and a piston-rod secured to the piston of each cylinder passes through stuffing-boxes in the two cylinder covers in the ordinary manner. The admission and escape of steam from the steam-cylinder is controlled by a piston-valve. From the valve a rod passes out through the end of the valve-chamber, and lies parallel with the piston-rod of the steam and the pump-cylinders. Between the two cylinders, the piston-rod has a crosshead attached to it, which embraces the valve-rod, and is free to slide to and fro upon it. Upon the valve-rod are two coiled springs of equal length, one on each side of the crosshead, and abutting at their opposite ends against collars upon the valve-rod. By this means, when the piston of the steam-cylinder passes beyond the centre of its stroke, one or other of the coiled springs is compressed, and tends to shift the valve over from one position to another. The valve is, however, prevented from moving over by a projection upon the valve-rod, which comes into contact with a stop carried by a lever. This lever is free to turn upon a pin at one end, and is held down by a spring at its other end. As the piston of the steam-cylinder completes its stroke a roller upon the crosshead of the piston-rod acts upon an incline on the lever above mentioned, and lifts the free end of the lever; the stop upon the lever is thereby moved out of the way of the projection upon the valve-rod, and the valve is at once thrown over by the action of the coiled spring, which had previously been compressed, and the valve is held over in its new position by the spring. As the piston of the steam-cylinder travels back, the stop-lever is drawn down by its spring, and prevents the valve from moving over until the completion of the stroke, when it is again free and shifted in the manner previously described. The width of the stop upon the lever, and that of the projection upon the valve-rod, may be so adjusted as to allow a slight movement of the valve at the centre of each stroke. By this means, steam may be partially or entirely cut off at the middle of the stroke, and so the steam in the middle of the cylinder may be allowed to work expansively. The extent of movement of the valve at the end of each stroke is limited by the projections upon the valve-rod alternately coming in contact with a fixed stop. Concussion is obviated by discs of vulcanized indiarubber interposed between them. The piston-valve is composed of two pistons at a distance apart from each other. Each piston serves alternately to admit steam to, and shut it off from the port leading from one end of the cylinder, and at the same time to open or close the communication of this port with the exhaust steam.

Steam is admitted to the central space of the valve-chamber between the two valves, and the exhaust is led off from its two ends. The ports for admitting steam to, and exhausting it from the two ends of the steam-cylinder enter the cylinder at some distance from its ends. From each port is a branch-port of contracted dimensions leading to the end of the cylinder. The piston of the steam-cylinder at the ends of its stroke passes beyond, and so closes the main port, whilst the contracted branch-port remains open. Thereby the piston is both brought up and started again quietly. The pumps are provided with indiarubber lip-valves, having the interior surfaces made of hard rubber and the exterior of soft rubber. When so made, no doubt the valves are much less liable to failure under heavy pressure.

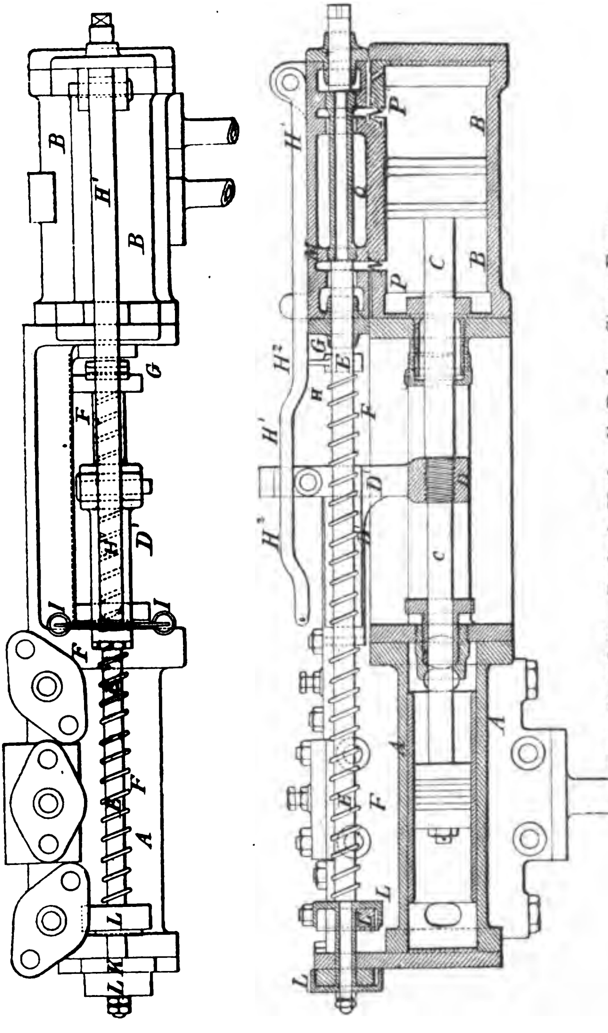
The apparatus for applying the brakes to the wheels of the guard's van is constructed in such a manner that it can be worked both by hand in the ordinary manner, and by liquid pressure from the continuous pipe of the hydraulic-brake apparatus, which is carried along the train. For this purpose, the link which rises up from the ordinary brake-gear below the guard's van, and which link has to be lifted to apply the brake, is coupled by a pin-joint to a cap which comes above a nut upon a vertical screw of the ordinary hand-gear. Below the cap is also a hollow tubular plunger, working in an hydraulic cylinder. When fluid under pressure is admitted to the hydraulic cylinder, the hollow plunger rises, whereby the cap and link are raised, and the brake is applied without moving the nut or the screw. The guard can also apply the brake by turning the screw by means of the ordinary hand-gear. The nut then travels upwards along the screw, carrying the cap with it and applying the brake. It is automatic or self-applying in case of severance by the accidental parting of the train. Fixed under each vehicle to which brakes are attached, are two separate cylinders, each containing a piston. Each piston is loaded by a spring, and the liquid under pressure, admitted to the cylinders from a continuous tube, overcoming the resistance of the springs, forces the piston to the top of the cylinders. Each cylinder thus contains fluid under pressure. One cylinder is to supply fluid under pressure to apply the brakes, and is fitted with a back stop-valve; the other cylinder is not so fitted, and, on the tube becoming broken, the fluid is free to escape from this cylinder, and the spring forces the piston in the cylinder to the bottom of its stroke. The movement of this piston is made to open a valve, by means of which the fluid under pressure in the first-mentioned cylinder is allowed to pass from there and exert its force on a piston actuating the brakes, and forcing them against the wheels. On the continuous pipe becoming broken, and the piston being forced to the bottom of the stroke, the valve, which is moved by the piston, is made not only to open communication from the cylinder under each carriage containing fluid under pressure to the brake-cylinder, but also to close the communication between the pipes which contain fluid, (by which the brakes are in the ordinary course applied from the engine or the guard's van), the brake-cylinders, and the other pipes running under the carriages.

The fluid can be supplied under pressure to the continuous-supply tube by machinery, either on the engine or in the guard's van. In order that the hose-pipes, which serve as connections between the carriages to couple-up the continuous pipes of the several carriages, may be readily uncoupled, and the escape of fluid under pressure at the same time prevented, a combined coupling and cock is provided. The kind of bayonet-coupling used is so arranged that a quarter turn of a handle is made to grip a swivel tied into the hose in close contact with the cock, the joint being made tight by two indiarubber rings. In moving this handle a quarter turn, it is caused to move the plug of the cock a quarter turn. The end of the plug of the cock, when brought into contact with the swivel end of the hose by means of the bayonet-joint, is made to turn a plug fitted into the swivel; and in this way, at the same time as a quarter turn is given to uncouple the hose, this movement, turning each plug a quarter turn, prevents the escape of fluid, and *vice versâ.* On the coupling-up of the hose, the quarter turn of the plug opens the cocks as is required; the bayonet-joint is also arranged in such a manner as to ensure that, when coupling-up, the two plugs are fair with each other, so preventing the possibility of one plug being open and the other shut when the coupling-up is completed. The hose, which serves as connections between the pipes of the brake-apparatus of the several carriages, is protected and strengthened by wire coiled round it. A pump is used for forcing the fluid under pressure, and the pump may be worked by steam by an excentric motion.

The piston of the pump is kept tight by employing a ring of leather, or other suitable material, similar to a metallic ring, but without a cut in it, to allow it to expand. Inside this leather ring is enclosed a metallic ring, cut as an ordinary piston-ring, the object of which is to spring the leather ring out, and keep it in close contact with the cylinder. Two such packing rings are used in each cylinder, in separate grooves in the piston. The water under pressure is admitted behind the rings in one groove from one end of the piston, and to the other groove from the other end. In order to place under pressure the fluid by which pressure-brakes are actuated, a friction-wheel is in some cases employed, running either on the periphery of one of the running-wheels of the carriage, or by a drum fixed on the axle of a vehicle, and so arranged that on the friction-wheel being forced against the revolving wheels the friction-wheel is made to rotate, and in doing so it winds up a chain. This chain is so arranged as to lift a piston working in a cylinder, the cylinder being full of water. On the piston being forced in by means of the chain, water is expelled. This water is connected by pipes with the brake-cylinder and applies the brake-blocks; and, therefore, as the piston is more or less powerfully forced inwards by means of the friction-wheel being more or less powerfully forced in contact with the revolving wheels, and thus bringing greater strain to bear on the chain by means of the piston, the water is more or less powerfully expelled; and the brakes may thus be applied with any degree of force. In cases where great leverage is required for applying the brake-blocks, instead of using several levers, as is frequently the case, an excentric is mounted on the brake-shaft, and by turning the excentric the brakes are applied. The degree of leverage can be regulated with ease by varying the throw of the excentric.

A speed-indicator is used in order that the driver or the guard of the train may at all times ascertain at what speed the train is travelling, and thus to what degree it is necessary to apply the brake when it is desired to stop the train; and also, when the brakes have been applied, to know how quickly the speed of the train is being reduced.

Figs. 51 and 52 show a steam-pump in section and in plan. A is the pump-cylinder, B the steam-cylinder, C the piston-rod uniting the pistons of the two cylinders, D is a cross-head on the piston-rod, D′ an arm extending from the cross-head and at its end embracing the valve-rod, E. F, F, are coiled springs surrounding the valve-rod, one on either side of the end of the arm, D′. These springs at their opposite end abut against collars upon the valve-rod. Upon one of these collars is a projection, G, which at the centre of each stroke comes against one or other side of a stop, H, on a lever arm, H′. This arm turns upon a pivot at one end, and is drawn downwards at its opposite end by coiled springs, I. There is a roller upon the cross-head, D. At the end of each stroke this roller comes against one or other of the inclines, H^2, on the lever, H′, and moves the lever upwards until the stop, H, has been moved clear of the projection upon the valve-rod. The valve-rod is then shifted endwise by whichever of the coiled springs is in compression, as before explained. The piston then travels back, and the stop comes into position to again control the movement of the valve. As before



Figs. 51 and 52.—Barker's Hydraulic Brake—Steam-Pump.

explained, the valve may, at the centre of each stroke, be allowed to move a short distance before being arrested by the stop, H, so as then to partly or entirely cut off the admission of steam to the cylinder. K is a fixed stop, which controls the amount of movement given to the valve at the end of each stroke; L, L are two collars upon the valve-rod, one on either side of the stop, K; L′, L′ are discs of vulcanised indiarubber carried by these collars to avoid shock; M, are the two pistons or discs forming the valve, at a distance apart upon the valve-rod. Each piston serves alternately to admit and to cut off steam from the ports, N N, which lead to the opposite ends of the steam-cylinder. Steam is admitted constantly to the central space, O, between the discs, and the exhaust is led from its two ends. P, P are small branch ports from the ports, N, to the extreme ends of the steam-cylinder. When the piston travels past and covers one or other of the ports, N, the steam enclosed in the space between the piston and the cylinder-ends forms a cushion to arrest the movement of the piston, as the steam can only escape through the small port, P, in the same way. When the valve has been shifted over at the end of the stroke, steam is at first admitted slowly to the cylinder-end through the small branch port until the piston has commenced to move back, and has travelled past the end of the port, N, steam then enters the cylinder freely through this port.

Fig. 53 shows a section of the pump. *a* is the outer valve-casing; *b* is an inner cylinder with holes, *b′*, in its sides; *c c* are rings of indiarubber made, as shown, with lips abutting against each other.

The lips are pressed against one another by the screwing on of the cover, *a′*, of the valve-case; the cylinder, *b*, is closed at the top, and at its lower end has a flange around it, between which and the bottom of the valve-case a tight joint is obtained by a ring of vulcanised indiarubber interposed between them. The lip-valves, *c*, are, as already explained, composed of an inner ring of hard rubber, *c′*, and an outer ring, c^2, of soft rubber with which the lips are formed, as shown. By constructing the lip-valves in this manner, partly of an inner ring of hard rubber, and partly of an outer ring with flexible lips of soft rubber, the soft rubber lips are prevented from being forced by high pressures into the holes of the cylinder, *b′*, and from being thereby destroyed.

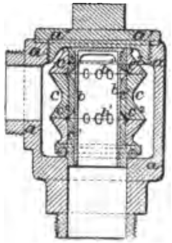
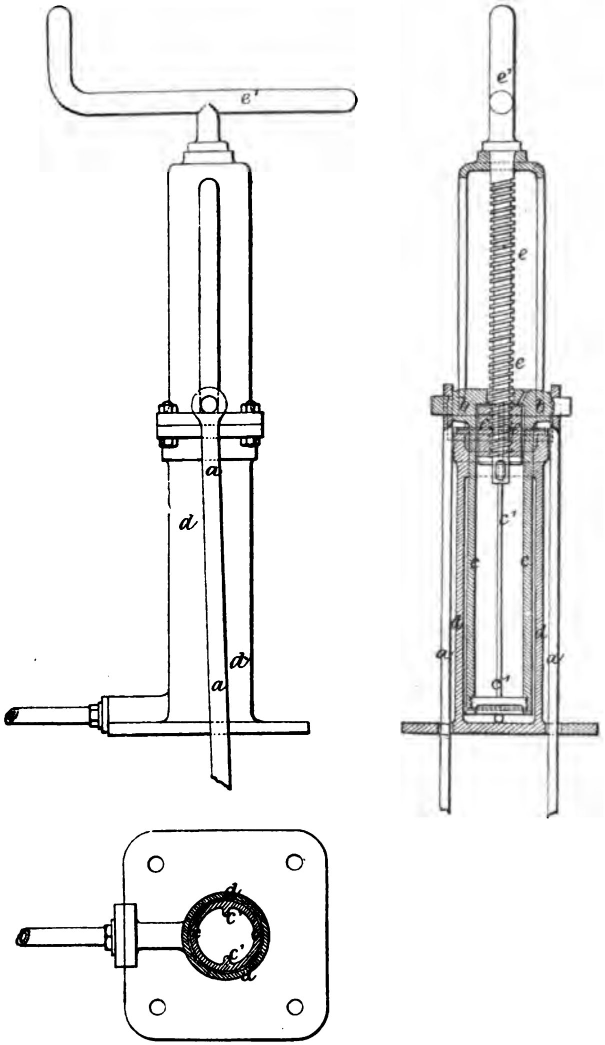


Fig. 53.—Barker's Brake—Section of Pump.

Figs. 54, 55, and 56, illustrate the apparatus for applying the brakes to the wheels of the guard's-van, so that it can be worked by hand in the ordinary manner, as well as by hydraulic pressure. *a*, *a* are the links which rise up from the ordinary brake-gear fitted below a guard's-van. In place of simply jointing these links to a nut which can be raised by turning a screw working with it, as in ordinary hand brake-apparatus, they are joined or coupled by a pin to a cap, *b*, from the under side of which descends a tubular plunger, *c*, which works in a hydraulic-cylinder, *d*, and is closed at the bottom, as shown. *e* is the screw passing freely through the cap at the top of the plunger, and *f* is the nut below the cap into which the screw enters. The nut is prevented from turning by grooves in its



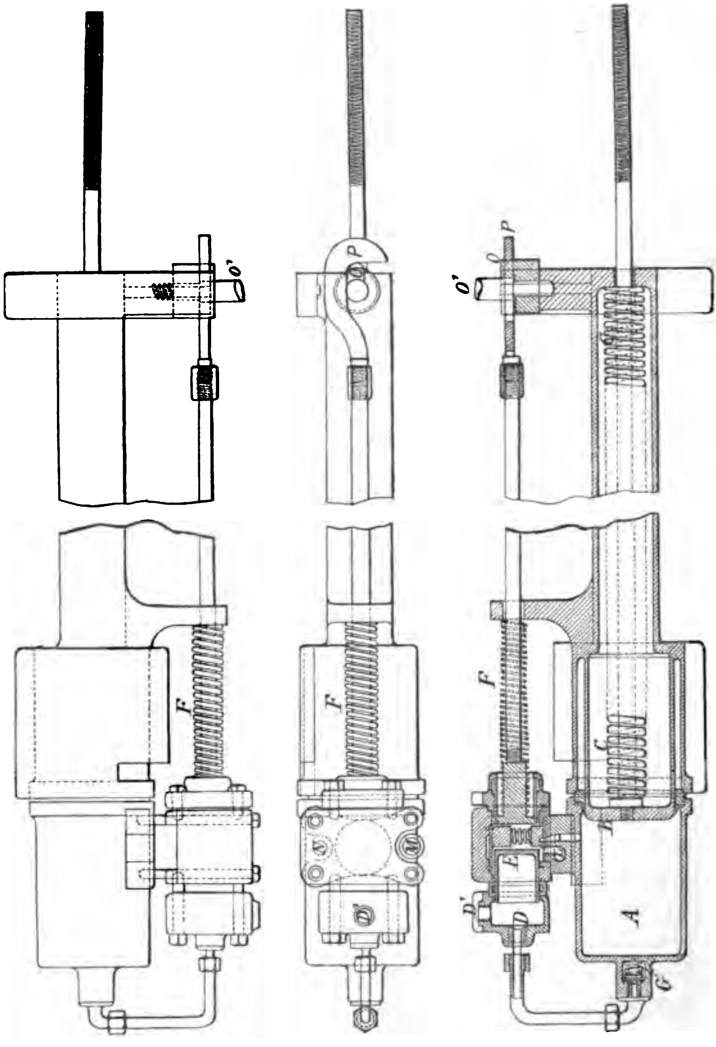
Figs. 54, 55, and 56.—Barker's Brake—Apparatus to apply Brake.

side fitting over projecting ribs, *c′*, formed down the interior of the plunger, *c*.

By this arrangement, the guard can apply the brakes by turning the screw in the ordinary manner by the hand-wheel, *e′*, at its upper end, or fluid under pressure can be admitted to the cylinder, *d*, and the plunger, *c*, so raised and the brake applied.

The cylinders and apparatus for actuating the brake-levers of the hydraulic automatic-brake are illustrated by Figs. 57, 58, 59. A is the chamber for containing a supply of water under pressure, and it is provided with a piston, B, pressed upon by a coiled spring, C. D is a smaller chamber fitted with a piston, E, pressed upon by a spring, F. Water under pressure from the pump is continuously supplied to the cylinder, D, through the opening, D′, from a pipe which is continuous through the train and is kept supplied with water. From the end of the cylinder, D, a pipe passes to the end of cylinder, A, and conducts the water under pressure to this chamber. Thus the piston of both cylinders are kept pressed outwards to the ends of their strokes. At the end of the pipe which leads into the chamber, A, from the chamber, D, there is a stop-valve, G, to prevent water passing back from A to D. The piston, E, of the chamber, D, extends through a valve-chamber, and through the piston a slot is formed in which is placed a small valve, I, pressed outwards from the slot by a coiled spring against the valve-face of the valve-chamber.

In this valve-face there are two ports; one port leading to the chamber, A, the other port, L, opening into a passage, which, by a union at M, is coupled to a



Figs. 57, 58, and 59.—Barker's Brake—Cylinders.

branch pipe from the main supply-pipe by which water under pressure is supplied to the brake-cylinder when the brakes are to be applied in the ordinary course. From the valve-chamber there is also another passage which, by a union at N, is connected with a pipe leading to the brake-cylinder. When the chamber, D, is filled with water, and its piston is pressed outwards to the end of its stroke, the valve, I, closes the port, and prevents the escape of liquid from the chamber, A; but the port, L, is uncovered, and water can pass through it from the main water supply-pipe to the brake-cylinders, whenever the brakes are required to be applied in the ordinary course. Should, however, there be an accidental severance of the train, and the automatic supply-pipe before mentioned become broken, the water in the chamber, D, will escape and its piston will be forced inwards by the spring which presses upon it. The valve, I, will by this movement be brought over and close the port, L, and at the same time uncover the port; water under pressure will then be forced from the chamber, A, through this port to the brake-cylinders, and the brakes will be applied automatically. Should it be desired at any time to throw out of action the above automatic arrangement or any one or other of the carriages of a train, it can be done by turning a crank or excentric, O, into such a position that it shall come against a hook, P, at the end of a rod which extends back from the piston, E, of the chamber, D, and so hold back this piston and prevent the valve, I, from being shifted, though the chamber, D, is not kept filled with water.

The framework of a carriage fitted with apparatus such as is above described is shown in Figs. 60, 61, 62.

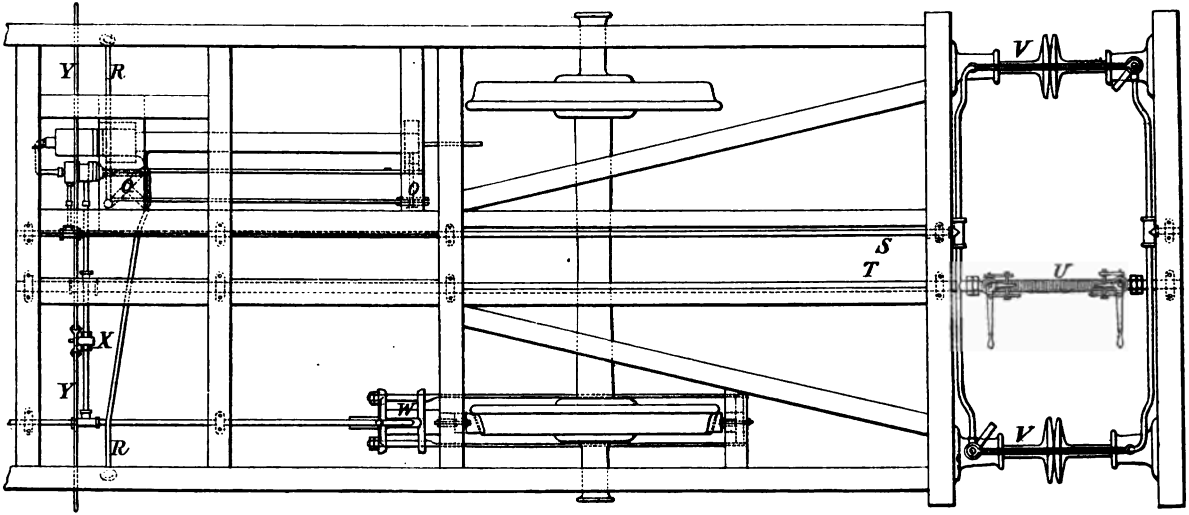


Fig. 60.—Barker's Brake.

The axis, o′, of the excentric has on it a crank-arm, coupled by a connecting-rod to one arm of a T-lever, Q. From the two other arms of this lever, rods, R, are conducted, one to one side of the carriage, and the other to the other side of the carriage, so that by drawing outwards or pushing inwards either of these rods a quarter turn may be given to the axis of the excentric.

In these figures, the automatic supply-pipe is

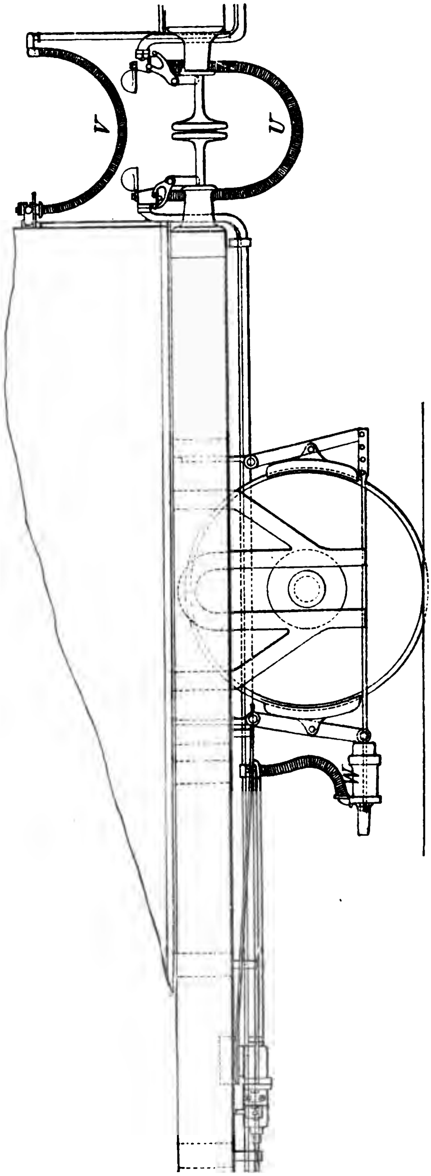


Fig. 61.—Barker's Brake.

shown at S, and the ordinary main supply-pipe at T. U are couplings which connect the portion of the main supply-pipe on one carriage with a portion of the main supply-pipe on the next carriage; and V, the couplings for the automatic supply-pipe; W are brake-cylinders for applying the brakes; X is a tap on the pipe leading to these cylinders; and Y, Y are the rods passing, one to

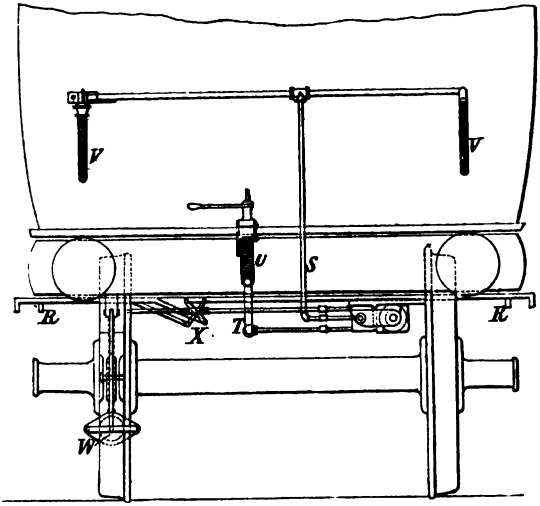
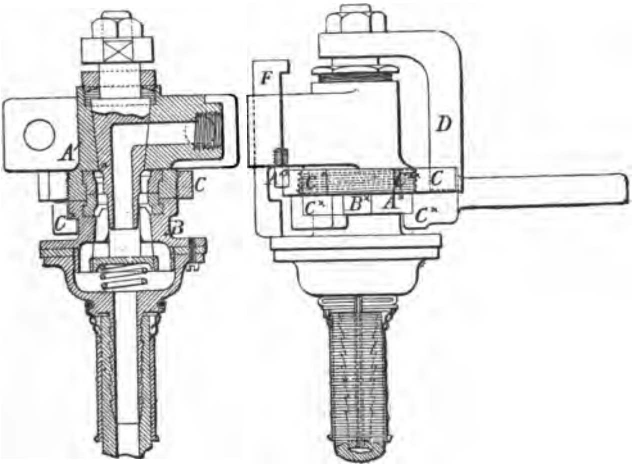


Fig. 62.—Barker's Brake.

one side of the carriage, and the other to the other side, by which this tap can be readily opened or closed, so that the brake apparatus on any one carriage of a train can be put out of action if required.

A combined coupling and cock for coupling and uncoupling between vehicles is illustrated by Figs. 63 and 64.

A is a cock, the shell of which is secured to the frame of one carriage; B is another cock at the end of a flexible pipe coupled to the end of the length of water supply-pipe on the next carriage. The plug of the cock, A, is prolonged beyond the shell in which it works and is formed square at its end to enter a corresponding recess in the plug of the cock, B. Around the end of the shell of the cock, A, is a screw-thread on



Figs. 63 and 64.—Barker's Brake—Combined Coupling and Cock.

to which screws a ring, C, which has projecting from it a lever-handle by which it can be turned, and also two lugs, $C^{\times}$, to hook over other lugs projecting from the shell of the cock, B. The ends of the shells of the two cocks which come together, each carry an elastic washer. When the two cocks are brought together end to end, the plug of the cock, A, enters the recess in the plug of the cock, B, a quarter-turn is then given to the ring, C, by its lever handle, and the lugs on the ring engage with the lugs, $B^{\times}$, on the shell of the cock, B, and as the ring, C, screws out the shell of the cock, A, it draws the elastic-washer carried by the cock, B, tightly against the washer carried by the cock, A, and forms a tight joint between them. At the same time, the plug of the cock, A, is turned so as to open it by means of an arm, D, which is secured to the plug of this cock and which enters a recess on the exterior of the ring, so that as the ring is turned and the two cocks drawn together, the cock, A, is simultaneously opened. As the plug, A, of the cock is turned, the plug of the cock, B, is compelled to turn with it, and so the two cocks are simultaneously opened, or when the ring is turned in a direction to release the one cock from the other then two cocks are simultaneously closed. When the shells of the two cocks are brought together, the lugs, $B^{\times}$, of the shell, B, enter between corresponding projections, $A^{\times}$, from the face of the shell, A; and the ring, C, being turned by its handle, the lugs, $C^{\times}$, upon it pass over the lugs, $B^{\times}$, and, the ring working along the screw, the two shells are drawn together. There is a finger, $C^{\times\times}$, on the ring, C, which coming against the stop-pin, $A^{\times\times}$, on the shell, A, prevents the ring unscrewing too far. The sliding-bolt, F, engages with a projection, C', on the ring, C, and prevents it from turning except when the bolt is pushed back by the two parts of the coupling being brought together. By inserting the part, B, in its place, the bolt is forced back until the notch in it comes to a place where the projection, C', on the ring can pass through it; but at other times the bolt prevents the cock from being accidentally opened.

Conclusion.—The Barker brake, as described, has many good points and shows a good deal of ingenuity on the part of the inventor. It has, however, the great objection of using water-pressure as its motor, and is, therefore, open to all the objections so frequently pointed out in regard to the use of water in apparatus of this kind in cold climates. The remedy proposed to overcome this by making a low-freezing compound of the liquid used, is a theoretical one which will always be found to be unreliable in daily practice on thousands of railway carriages.

CHAPTER XII.

SANDERS' VACUUM CONTINUOUS-BRAKE.

THE exhaust-tube, which runs from end to end of each carriage, communicates with a small exhaust-box under the middle of the carriage. From this box a tube proceeds for a short distance towards one end of the carriage, and a like tube in the opposite direction. These tubes communicate respectively with rigid cylinders, furnished at their lower ends with flexible pistons or diaphragms. The rods of the said pistons are connected respectively with the ends of a lever. One of the cylinders is of slightly larger diameter than the other, and when the cylinders are both exhausted, the exhaust in the one cylinder more than balances the exhaust in the other cylinder, and the lever connecting the piston-rods of the cylinders is thereby brought into the position in which, by means of the connecting rods, it draws the brake-blocks from the wheels, or in other words holds them out of action. The end of that pipe which communicates between the exhaust-box and the cylinder of smaller diameter is furnished with a valve opening outwards, so that the valve offers no impediment to the exhaustion of the cylinders. But when the exhaustion of the box is destroyed, the valve instantly closes and preserves the exhaustion in the cylinder of smaller diameter.

When air is let into the exhaust-pipe, running under the carriage, by fracture of the pipe or by the driver, the vacuum in the pipe is destroyed.

The vacuum in the cylinder of larger diameter is also destroyed, while the vacuum in the cylinder of smaller diameter is preserved. The flexible piston of the latter being no longer counterbalanced by the piston of the other cylinder, instantly rises, and, changing the position of the lever, joining the two piston-rods, presses the brake-blocks forcibly against the wheels, and brings the train to rest. When the brake-blocks are to clip the same wheel on opposite sides, the arrangement is as follows:—To the brake-block hangers on the outer side of each wheel a cross shaft connection is used, turning in bearings on the hangers. At the ends of the cross shafts are short vertical levers, the lower end of each of the levers being connected by a connecting-rod to the brake-block on the opposite side of the wheel. The upper end of each of the levers is connected with the lever of the working mechanism, that is, the lever connecting the rods of the flexible pistons of the cylinders.

When, by the destruction of the vacuum, motion is given to the lever connecting the piston-rods, the connecting-rods connecting this lever with the small lever on the outer side of the brake-blocks are drawn inwards. The result of this motion is to cause the lower end of each of the small levers to draw inward on the inner side of the wheel, and thus bring the train to rest by a clipping action of two brake-blocks on the opposite sides of the wheel.

As the arrangement of exhaust-cylinders, already described, had for its object to work the brakes by

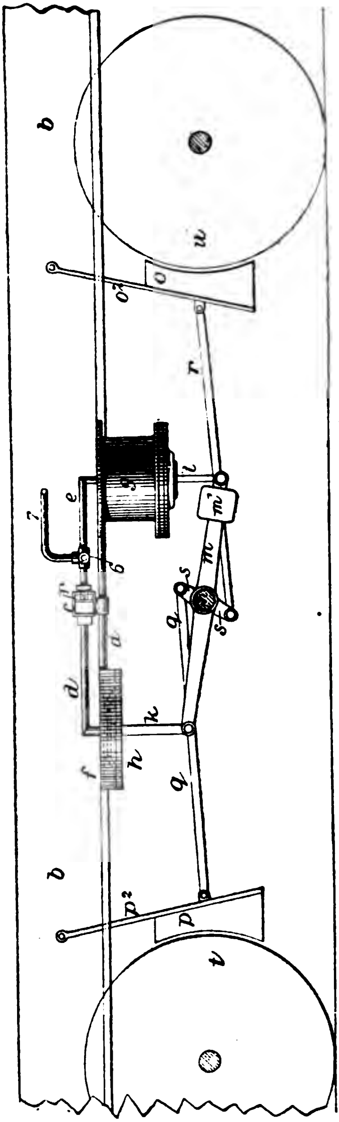
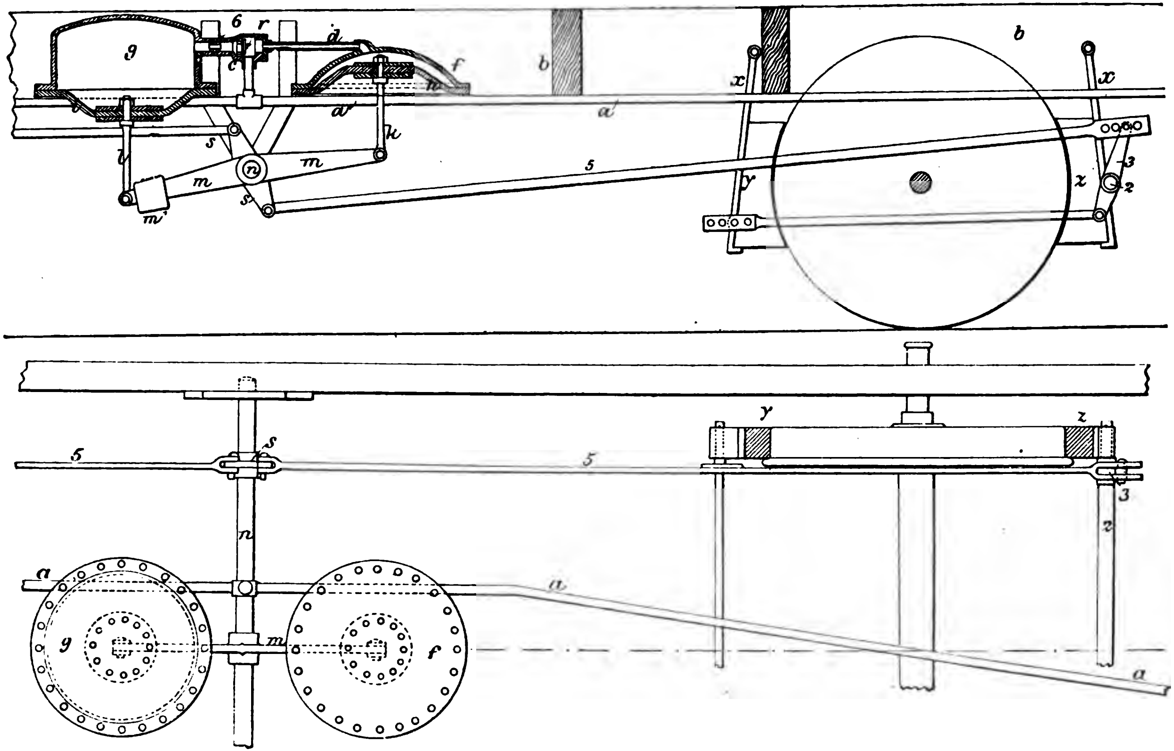


Fig. 65.—Sanders' Vacuum-Brake.

pressing brake-blocks in opposite directions between the two wheels, the arrangement of the clipping action is to produce a double action on the wheel by the drawing inwards of the connecting-rods, and the position of the exhaust-cylinders requires to be reversed. That is, the cylinder of larger area in the first described arrangement, with single brake-blocks, becomes the cylinder of smaller area for double brake-blocks.

Fig. 65 represents in elevation the mode of working the brake when the brake-blocks are applied only to the inner side of the two pairs of wheels between which the brake mechanism is situated. Figs. 66 and 67 represent the mode of applying the blocks to the



Figs. 66 and 67.—Sanders' Vacuum Brake.

wheels by pressure on opposite sides of the same, or the clipping action. The arrangement of the mechanism by which the vacuum is made to work the brakes is the same in both of the arrangements. The exhaust tube, *a*, running underneath the carriage, *b*, communicates with the exhaust box, *c*. From this box a tube, *d*, proceeds towards one end of the carriage, and a like tube, *e*, in the other direction; *f*, *g* are rigid cylinders made of cast-iron, and having at their lower ends flexible pistons or diaphragms marked *h*, *i* respectively. The rods, *k*, *l*, of the flexible pistons are connected to the ends of the lever, *m*, turning on the shaft, *n*. The cylinder, *f*, is of larger diameter than the cylinder, *g*, and when both cylinders are exhausted, the pressure of the atmosphere operating upon the greater area of the flexible piston, *h*, the apparatus is brought into the position represented in Figs. 65 and 66; that is, the piston, *h*, of the cylinder, *f*, of larger diameter, is drawn into its cylinder, while the piston, *i*, of the cylinder, *g*, of smaller diameter, is brought to its extreme position outside its cylinder.

The brake-blocks, *o*,*p*, Fig. 65, carried by the hangers, o^2, p^2, respectively, are connected by means of connecting-rods, *q* *r*, to the short lever, *s*, on the axis, *n*; and the pistons, *h*, *i*, being in the position represented, the brake-blocks, *o*, *p*, are supported from or held out of action on the wheels, *t*, *u*.

That end of the pipe, *e*, which terminates in the exhaust box, *c*, is furnished with a valve, *r*, opening outwards: that is, into the box, *c*. The valve, *r*, consequently offers no obstacle to the exhaustion of the cylinder, *g*; but when the exhaust in the box, *c*, is destroyed, the valve, *r*, closes, and thereby maintains the exhaustion in the cylinder, *g*, while air passes by the pipe, *d*, into the cylinder, *f*.

The atmospheric pressure on the outside of the piston or diaphragm, *h*, is now balanced by an equal atmospheric pressure on the inside of the piston, *h*; but the atmospheric pressure on the piston, *i*, of the cylinder, *g*, being unbalanced, the piston returns into its cylinder by the atmospheric pressure, and by the operation of the piston-rod, *l*, on the lever *m*. The position of the lever, *m*, is so changed that the short lever, *s*, acting through the connecting-rods, *q*, *r*, presses the brake-blocks, *o*, *p*, into contact with the wheels, *t*, *u*, and brings the train to rest. Thus, when air is let into the pipe, *a*, either by fracture, the severing of the train, or by the action of the guard or driver, the brakes fly into action at once. To work brakes clipping the wheels on which they act on opposite sides, we will describe the action with reference to only one pair of wheels. Figs. 66 and 67 are the hangers to which the brake-blocks, *y*, *z*, are suspended. 2 is a cross shaft working in bearings on the outer side the hanger, *x*, the shaft 2 connecting the outer blocks on opposite sides of the carriage.

On the cross shaft, 2, is a lever, 3, the lower end of the lever being connected by a connecting-rod to the brake-block, *y*, at the inner or opposite side of the wheel.

The upper end of the lever, 3, is connected with the lever, 5, of the exhaust mechanism, through the connecting-rod, 5, when, by the destruction of the vacuum, motion is given to the levers, *m* and *s*, the connecting-rod, 5, connecting the lever, *s*, to the lever, 3, on the outside of the brake-blocks, *y*, *z*, is drawn inwards, that is, from the end of the carriage towards the middle.

The result of this motion is to cause the lower end of the lever, 3, to draw inwards the brake-block, *y*, on the inner side of the wheel, and thus to effect a clipping action of the two brake-blocks, *y*, *z*, on opposite sides of the same wheel. On comparing the arrangement, Fig. 65, with that represented in Figs. 66 and 67, it will be seen that the single brakes in Fig. 65 are brought into action by the motion of the connecting-rods, *q*, *r*, outwards, or from the centre of the carriage towards the ends, while the double brakes, *y*, *z*, in Figs. 66 and 67, are brought into action by the motion of the connecting-rods, 5, 5, in opposite directions; that is, by motion of the rods, 5, 5, from the ends towards the middle of the carriage.

This difference between the working of the single and the double brake-blocks, requires that the cylinders, *f*, *g*, shall have a position in the arrangements, Figs. 66 and 67, the reverse of that which they have in the arrangement, Fig. 65, the smaller cylinder, *g*, in Fig. 65, being on the right of the larger cylinder, *f*; but the positions of the cylinders are varied to suit the particular arrangement of brake-mechanism to which they may be applied. In either of the arrangements described, the cylinders, *f*, *g*, may be of the same diameter, provided that the two arms of the lever, *m*, are of different lengths. The brakes can be worked positively instead of negatively as described; that is, instead of the destruction of the exhaust being employed to bring the brakes into action, the production of an exhaust may be employed to effect the direct action of the brakes on the wheels. When the positive method of working the brakes is resorted to, the cylinder of larger diameter, and the exhaust-box, *c*, are dispensed with.

By means of a three-way cock or valve situated at 6, Figs. 65 and 66, signalling on the train may be effected. By turning the cock into the position indicated in Fig. 65, the pipe, 7, connected with the signal, may be put into communication with the exhaust, and by turning the plug of the three-way cock or valve through a semi-rotation, the signalling tube, 7, may be disconnected from the exhaust. The stop-cock is kept in its normal position, in which it connects the two cylinders by a spring, and by means of a cord or chain, not shown, the guard or a passenger may act upon this valve and cause an alarm to be sounded.

It is necessary that the stop-cock at 6 should not have a passage through its plug sufficient to allow enough air to enter wholly to destroy the vacuum produced in the pipe, *a*, by the steam-jet, as in this case the action of the brake mechanism would be interfered with. But so long as any material exhaustion is maintained in the pipe, *a*, insufficient to raise the weight, *m'*, on the lever, *m*, the brakes will be kept out of action.

Mr. Sanders has recently improved his brake in dispensing with canvas and indiarubber, and in combining the action of the two drums in one cast-iron cylinder, as shown in Figs. 68 and 69. When the brake is "off," the vacuum is maintained on both sides of the piston by a small ejector on the engine. The piston is then held at one end of its stroke by the overbalancing pressure due to the greater effective area of the side, A, the effective area of the side, B, being reduced by the piston-rod.

The admission of air through the continuous pipe to

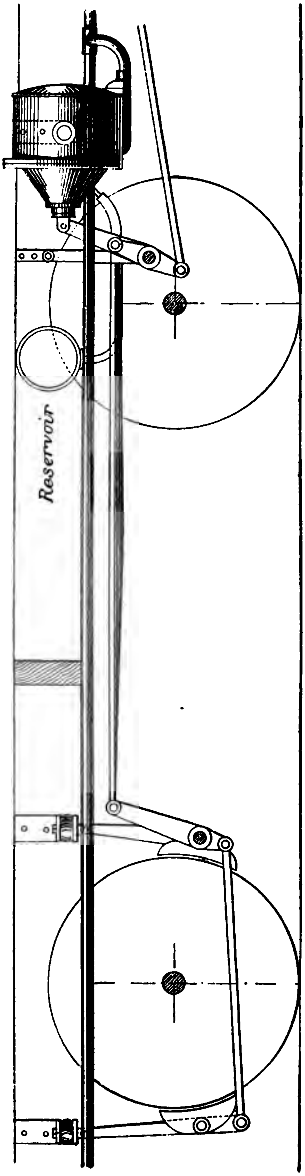


Fig. 68.—Sanders' Brake (Improved).

the side, A, of the piston, causes the brake to be instantly applied by the vacuum maintained on the opposite side, B, and in the reservoir by the check valve, E. The brake is released by restoring the vacuum in the continuous pipe by the large ejector, and on the side, A, of the piston.

The latest improvement in Sanders' brake may be briefly stated thus:—There is one brake-cylinder, D, Fig. 70, on the engine, and one on each carriage; a single line of pipes extends the length of the train with a branch to one end of each brake-cylinder; from the opposite end of each cylinder a pipe leads to a small reservoir, one for each carriage. There is a small hole through each piston for the passage of air. When the pipe-couplings are being disconnected, during the time that a partial vacuum exists in the pipe, there are no valves to prevent the inflow of air and the consequent application of the brakes. There is a dummy coupling at each end of each carriage, to close the pipe-coupling when not connected to the coupling of an adjoining carriage.

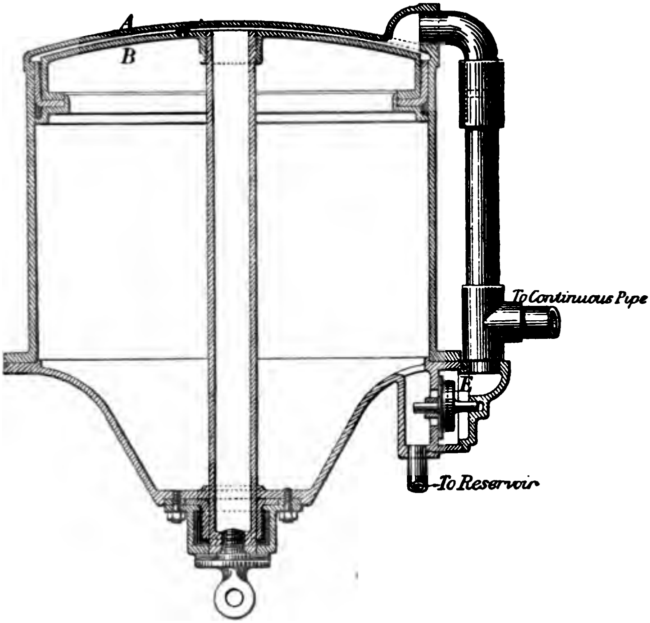


Fig. 69.—Sanders' Brake (Improved)—Cylinder.

There is a small ejector on the engine which maintains a partial vacuum in the main-pipe, in each cylinder on both sides of the piston, and in the small reservoirs on the carriages. The operation is as follows: The small ejector, B, Fig. 70, is started, and a partial vacuum is created throughout the train, which holds the blocks from the wheels. The brakes are applied by opening a valve, C, on the engine or in the van, which lets air into the pipe and cylinders on one side of the piston. The small holes in the piston allow the brakes to leak off, but in a length of time greater than the time required to make an ordinary stop. When carriages are detached from a train, the act of uncoupling applies the brakes, which must then be allowed to leak off before the vehicles can be moved.

The amount of leakage must therefore be proportioned to two conditions. If it is too great, it will interfere with the operation of stopping the train; if it is too small, it will cause delay in shunting operations, or in attaching or detaching carriages.

References to the engine, Fig. 70:—A, large ejector for creating the vacuum; B, small ejector for maintaining the vacuum; C, driver's valve for applying brakes; D, automatic vacuum-cylinders for engine-brakes; E, vacuum-gauge, for indicating condition of brakes; F, steam cock for large ejector; G, steam cock for small ejector.

Conclusion.—The Clayton brake, used by the Midland Railway Company, is an automatic vacuum-brake, almost identical with the Sanders' brake just described; the only difference being that the cylinder is placed inside the reservoir. It is also provided with a leak-hole in the piston, so as to avoid the use of valves for communication between the two sides of the piston. These arrangements, although apparently simple in construction, give rise to great complications in working; in fact, the couplings are simply hose and con-

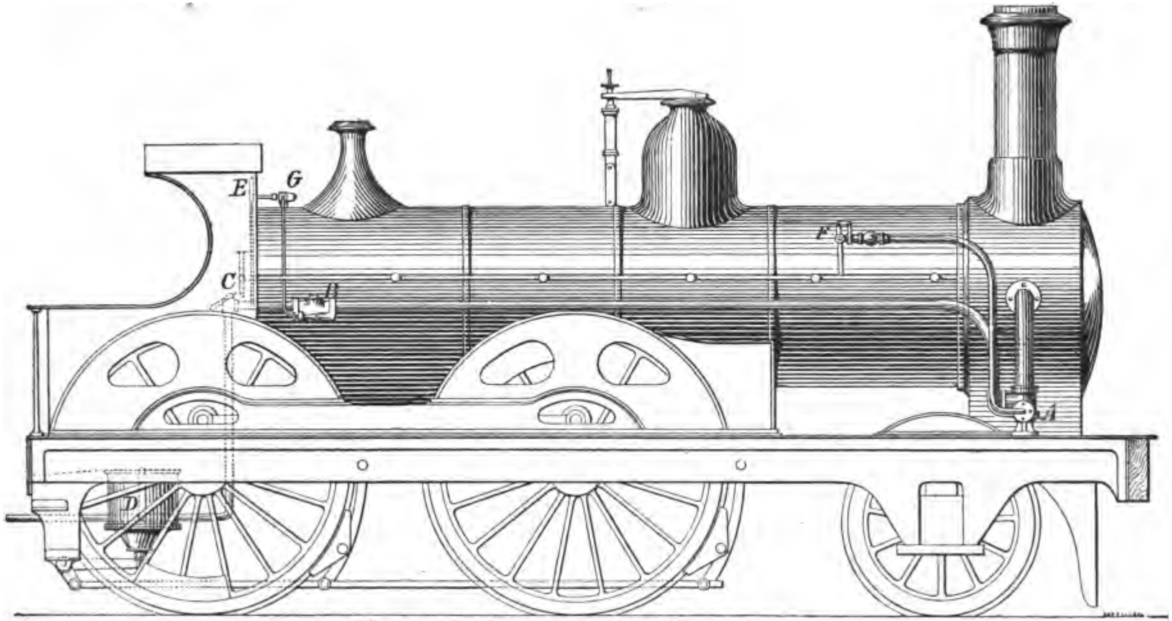


Fig. 70.—Sanders' Brake—Latest Improvement.

nections which admit air to the main pipe when they are uncoupled, thus setting the brakes on both portions of the trains, requiring the brakes to leak off before the carriages can be moved. This condition is very inconvenient in shunting. On inclines, the leakage arrangement must be considered dangerous. If a train breaks in two, the brake-power vanishes very quickly, and the rear portion of the train will run back, and may give rise to accidents. There can therefore be no doubt but that the leak-hole arrangement is an utterly unsafe and bad contrivance. But, to do away with this, many alterations would be necessitated.

First, the couplings must be so made as to prevent the air from entering the main pipe when uncoupled This should be obtained by placing cocks on the main pipe, or by providing the couplings with automatic valves, as is done with the Westinghouse couplings. If the leak-hole is done away with, a valve must be added to establish a communication between the brake-cylinder, the brake-pipe, the reservoir, and the atmosphere. This can only be obtained by means of a valve with three functions, having an action similar to that of the Westinghouse triple-valve. To provide for the necessity of isolating the apparatus on one carriage, without influencing the rest of the train, a cock should be placed between the brake-pipe and the reservoir. To provide for the necessity of releasing the brake by hand, in exceptional cases, on any one carriage, a release-valve should be attached to each brake-cylinder.

It is clear from this that an automatic vacuum-brake requires an apparatus equally complicated with an automatic air-brake, and the opinion that a vacuum-apparatus is simpler than a high-pressure one, is nothing less than erroneous.

All vacuum-brakes have, besides, the great disadvantage of voluminous cylinders and reservoirs, giving rise to great bulk and great weight.

CHAPTER XIII.

THE WESTINGHOUSE AUTOMATIC BRAKE.

THE Westinghouse automatic brake is worked by compressed air stored in a main reservoir on the engine, and in small reservoirs, one on the engine, one on the tender, and one on each carriage; all of them connected by a pipe running throughout the train. There are also on each vehicle a triple-valve and a brake-cylinder with pistons connected to the brake-levers. In maintaining the pressure in the brake-pipe, the brakes are kept off; but in letting the air escape from the brake-pipe, purposely or accidentally, the brakes are instantly applied, allowing air to pass from the small reservoirs into the brake-cylinders.

This brake is illustrated in one view by Plate VII., as fitted to an engine and tender. The literal references correspond to those of Plate VIII. The air-pump and the small steam-pump are in one piece, fixed to the side of the boiler of the locomotive. The engine works the air-pump, by which air is forced into the main reservoir fixed to the lower side of the engine footplate. The pressure of air is considerable, being from 80 lbs. to 100 lbs. per square inch. The compressed air is turned into the main or continuous pipe by the driver's valve, the pressure being indicated by the pressure-

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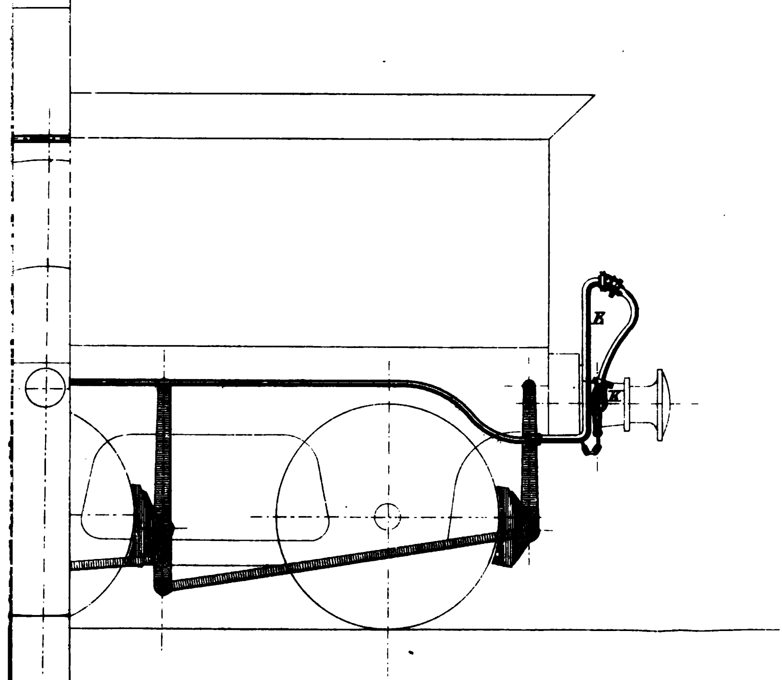
Plate VII.



THOS KELL & SON. LITH. 40, KING ST COVENT GARDEN.

gauge. The compressed-air passes through the triple-valve into the small reservoir, but not into the brake-cylinder; and, for a train of carriages, the air would also pass along the coupling hose between the carriages, and fill all the small reservoirs. The air is prevented from entering the brake-cylinder by the triple-valve, which is fitted with a slide-valve having top and bottom ports. The pressure of the air lifts the slide over the port leading to the brake-cylinder; and, the pistons in the cylinder being held apart by strong spiral springs, the blocks are kept off the wheels.

When the driver perceives danger or requires to stop, he lets a little air out of the main pipe, and the slight reduction of pressure in consequence causes the triple-valve slide to drop, by which movement the top port which leads to the brake-cylinder is opened. The air in the small reservoir enters the brake-cylinder between the two pistons and forces them asunder, and so applies the brake, with a force equal, it may be, to 4,000 lbs. total pressure. A reduction of 20 per cent. in the brake-pipe will cause the triple-valve to drop entirely, and release the air in the small reservoir and fully set-on the brakes.

The distance from the reservoirs to the brake-cylinders averages not more than 2 feet, and consequently there is no perceptible loss of time in compressed-air of 90 lbs. pressure per inch passing from one to the other. The contents of the pipe on each carriage is about 300 cubic inches; and this quantity, added to 60 cubic inches per carriage, makes 900 cubic inches for a train of fifteen vehicles, which has to escape at high pressure, in order to set the brakes with full force. This operation occupies 1¼ seconds.

The brakes are taken off by reopening the passage from the main reservoir to the brake-pipe. By this movement the pressure in the brake-pipe is restored, the small reservoirs are recharged, air is discharged from the brake-cylinder, and the springs within the cylinder withdraw the brake-blocks from the wheels.

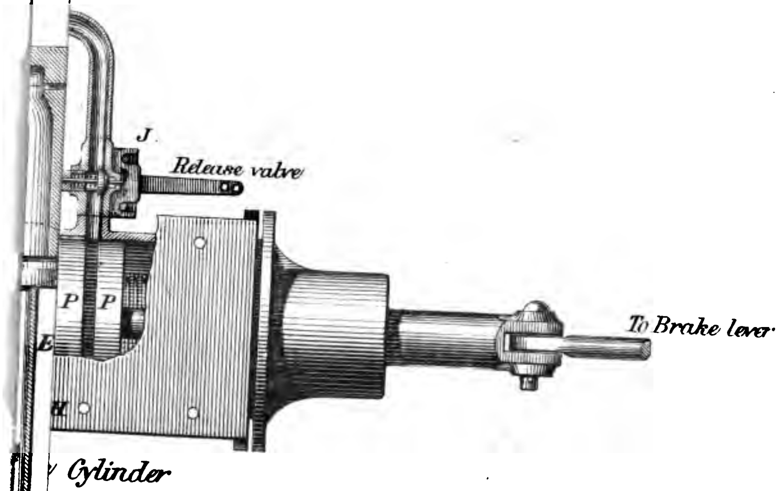
Provision is made to prevent the accidental application of the brake by leakage, by the introduction of a leakage-groove in the brake-cylinder, as well as in the slide-valve of the triple-valve, to be afterwards described. When a small flow of air from the reservoirs to the brake-cylinder is caused by leakage in the brake-pipe, the air flows by these grooves into the atmosphere, without moving the pistons. When reduction of pressure is made for the purpose of applying the brake, the grooves are closed, and thus all escape of air is prevented. A stop-cock is placed on a branch from the main or continuous pipe for the purpose of closing the connection with the triple-valve on any one vehicle, without interfering with the operation of the brakes upon the others. A release-valve, worked by hand from either side of the train, may be opened, if necessary, to release the air from the brake-cylinder.

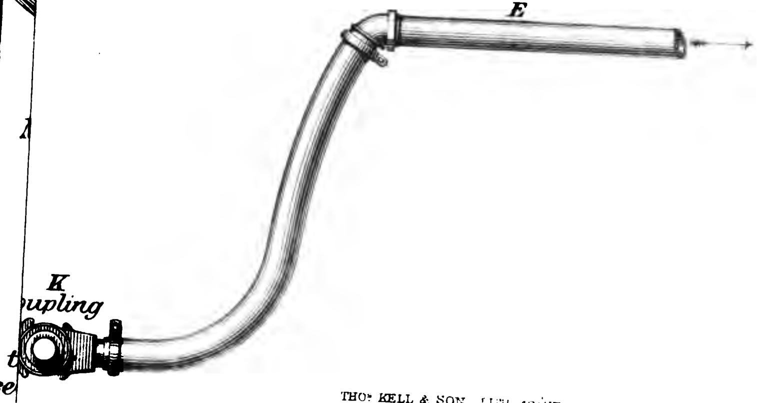
Engine and Tender.

Plate VIII. is a diagram showing the operation of the brake, from the air-pump to the end of a vehicle. It is not exact, nor to scale, but is intended simply to show the relation which each part bears to the whole. A is the steam-cylinder, B the air-cylinder, fixed on the side of the boiler, C is the main reservoir beneath the foot-plate. The pump makes from 20 to 60 strokes per

W

Plate VIII.





THOS KELL & SON LITH. 40, KING ST COVENT GARDEN.

mile, and the reservoir is capable of holding 10 cubic feet of air. The pressure-gauge, d^2, is fixed inside the cab and in front of the driver; so also is the steam-cock, *a*, for regulating the speed of the pump and the air-pressure in the main reservoir. A one-inch exhaust-pipe leads to the smoke-box.

The driver's valve, D, is fixed in front of the fire-box and immediately before the driver; it has one connection to the main reservoir, and a second connection to the brake-pipe, E, running the entire length of the train. In its normal position, it maintains about 10 lbs. per square inch more pressure in the main reservoir than in the brake-pipe.

The driving-wheel brake-blocks are generally worked by two brake-cylinders. From the brake-pipe, E, is a branch on both the engine and the tender, to the triple-valve, F, which is in communication with the small reservoir, G, on each, and by a pipe with the brake-cylinder. Cocks, *i*, serve to close the branch pipe, if required. The brake-pipe, E, has, at the end of the tender, a hose, with coupling attached, which unites with a similar coupling and hose on the following vehicle. A drip-cup is placed on the main pipe, E, to catch any water which might otherwise pass into the train.

CARRIAGE AND VAN.

The apparatus for each carriage is similar to that of the tender, except that an eight-inch double piston is used instead of a vertical cylinder, which is only applied to tenders for convenience' sake, and in order to accommodate the existing brake-gear.

The connections between carriages are made with flexible tubing of 1 inch internal diameter. One end of each piece is fitted on a nipple, by which it is fastened to the brake-pipe. To the other end is attached a coupling having a side opening fitted with an indiarubber packing-ring, constructed so as to prevent the escape of air when uncoupling, to be more fully described in due order. When two of these couplings are joined together, the air-pressure within serves both to tighten the joint and to hold the two couplings firmly together. If the coupling be drawn apart forcibly by the separation of the train, the brakes are applied in consequence of the escape of air, but no damage is done to the coupling.

AIR-PUMP.

The direct air-pump is shown in section, Fig. 71. Steam from the locomotive-boiler enters the upper cylinder between the two pistons of the main valve, 14. The upper piston being of greater diameter than the lower, the tendency of the pressure is to raise the valve, unless it is held down by the greater pressure of the piston, 20, working in its cylinder above it, which piston is held down by the pressure of steam admitted from the chamber, A; this chamber is always in communication with the space between the two pistons of the main valve by means of a passage, *t*.

As shown in the drawing, steam is entering past the lower piston of the main valve, and forcing the main piston, 6, upwards. As the main piston completes its upward stroke, the plate, 10, pushes up the rod, 12,

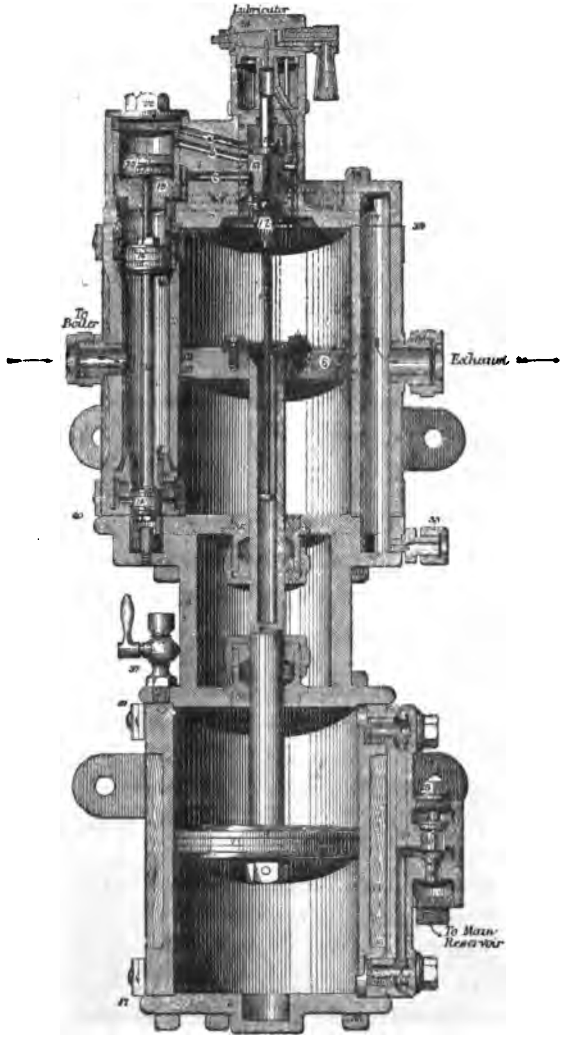


Fig. 71.—Westinghouse Automatic Brake—Direct Air-Pump.

and with it the slide-valve, 13, closing the passage, *a*, from the chamber, A, to the cylinder 19, and at the same time opening the exhaust-passage, *b*, to the atmosphere through *c*, which relieves the pressure on the top of the piston, 20. The relief of the pressure on the piston, 20, permits the steam in the main-valve chamber to raise the main valve and enter to the upper side of the main piston, 6; and at the same time it exhausts the steam on the lower side. On completing its downward stroke, the main piston again draws the rod, 12, and the valve, 13, to the position shown, reversing the position of the main valve, and consequently the stroke of the main piston. A lubricator of special design is screwed into the top head of this cylinder.

THE TRIPLE-VALVE.

A three-inch triple-valve is shown in section, Fig. 72. The construction and mode of operation of this valve are as follows:—Enclosed in a case 1, is a piston 5, carrying with it a slide-valve, 6, which covers the port, *a*, to the brake-cylinder, and, in the position shown, establishes a communication between it and the atmosphere by the exhaust-cavity, *b*. Compressed-air from the main pipe enters the lower part of the case, and forcing up the piston, 5, feeds past it into the reservoir through the groove, *d*.

Equal pressures are thus maintained in the reservoir, the triple-valve, and the brake-pipe, whilst the brakes are off. For the purpose of graduating the brake with the greatest nicety, a small valve, 7, is introduced into the slide-valve, 6. The action is as follows:—Upon a slight reduction of pressure in the brake-pipe being made, the piston, 5, having a limited movement without affecting the valve, 6, will descend, thereby closing the feed-groove, *d*, at the same time

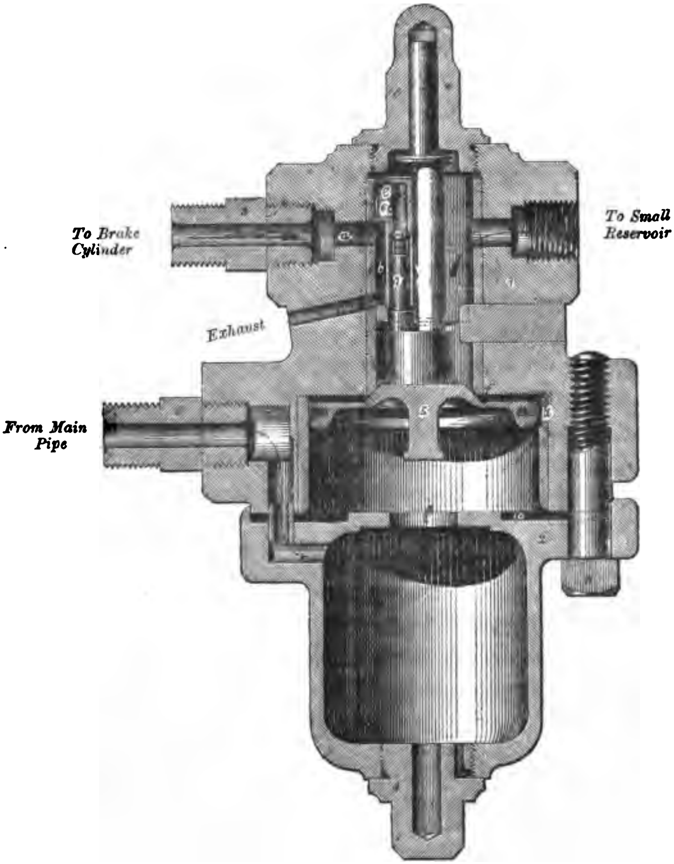


Fig. 72.—Westinghouse Automatic Brake—Triple-Valve.

unseating the valve, 7, which thus opens the passage, *e*.

The slide-valve, 6, then moves until the passage, *e*, opens into the port, *a*, leading to the brake-cylinder, the communication from which to the exhaust is at the same time cut off.

Further downward movement of the slide-valve, 6, is arrested by the decrease of pressure above the piston, caused by the air flowing into the brake-cylinder. So soon as the pressure in the reservoir is thus reduced a little below that in the brake-pipe, the piston, 5, moves up of its own accord and closes the valve, 7, while the slide-valve, 6, retains its position. By simply regulating the reduction of pressure in the brake-pipe, and causing the motion of the piston and graduating-valve, 7, to be repeated, the driver can gradually introduce any desired pressure into the brake-cylinder, from zero to full power. However, if a considerable reduction of pressure in the main-pipe is suddenly made, the piston, 5, is seated on the leather gasket, 10, while the port, *a*, is entirely uncovered, and the brakes are thus applied with full force. To release the brakes, air is again admitted from the main reservoir to the brake-pipe by means of the driver's valve. This acting against the reduced pressure in the small reservoir forces the piston, 5, into the position shown, thus permitting the air in the brake-cylinders to exhaust, whilst at the same time the reservoirs are re-charged.

The only moving parts of the triple-valve, which is an ordinary piston and slide-valve moving together as one piece, do not make so many motions in fifteen years as are made by the piston and slide-valve of the locomotive in one day.

DRIVING-WHEEL BRAKE-CYLINDER.

Cylinders of this form, Fig. 73, are used to apply the brake to the driving-wheels of engines, where the piston cross-head is shown attached to the brake-blocks suspended between the driving and trailing wheels. Air is admitted above the piston, 5, by the downward movement of which the brakes are applied.

DOUBLE-PISTON BRAKE-CYLINDER.

When air is admitted to the cylinder, Fig. 74, the two pistons, 4, 4, are thrust outwards with equal force by air at about 80 lbs. per square inch entering the cylinder.

When the air is allowed to exhaust into the atmosphere through the exhaust port, *b*, in the triple-valve, the springs inside the brake-cylinders push back the pistons and release the brake-blocks from the wheels.

HOSE COUPLINGS.

There has been a desire to have a coupling which is so constructed as to establish a free opening by the simple fact of connecting it, and so as to close automatically when uncoupled in the ordinary way. This would then dispense with the cocks in the main pipe. Mr. Westinghouse has devised two couplings which solve this problem entirely by placing valves in the coupling ends. These valves open automatically when the couplings are joined together, and close when disconnected; but they remain open to apply the brakes when drawn open by the accidental separation of the train. These couplings have been applied to all

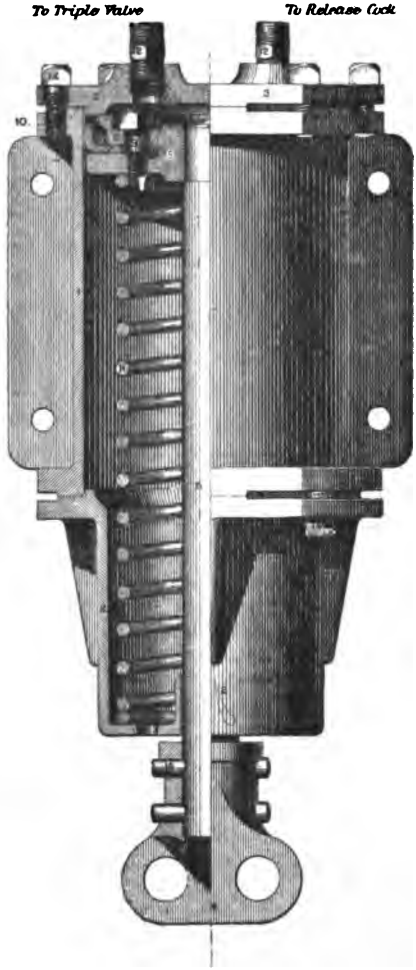


Fig. 73.—Westinghouse Automatic Brake—Driving-Wheel Brake-Cylinder.

trains in this country. However, although these automatic couplings are quite right in principle and ingenious to the extreme, most railway engineers raise objections to the great complication of their parts as compared with the plain Westinghouse coupling without valves, which merits admiration on account of its simplicity and efficiency.

Brake couplings at all times will have to stand rough usage and a good deal of knocking about, and therefore the simpler they can be made the better; hence, it is preferable to use the plain coupling and cock in the brake-pipe instead of the automatic coupling described. This change, it is stated, is now being made on all lines in the kingdom.

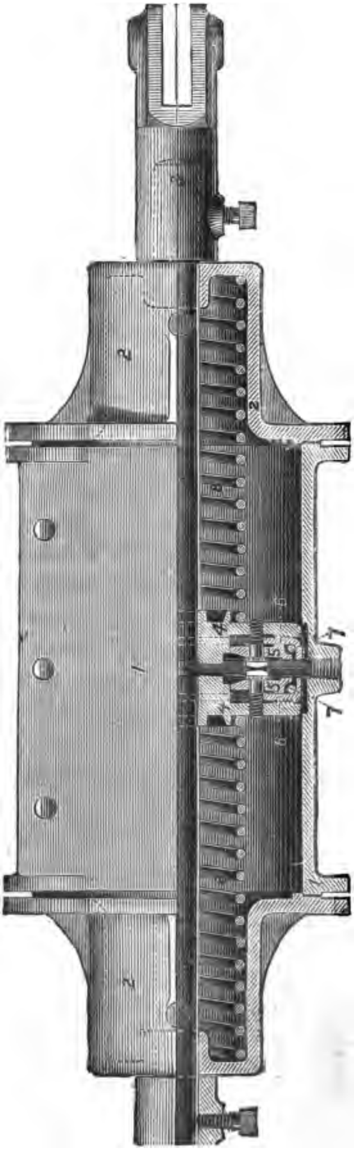


Fig. 74.—Westinghouse Automatic Brake—8-inch Double-Piston Brake-Cylinder.

With these non-automatic couplings the cocks in the main pipe must always be opened after the couplings have been united, and must be closed before they are separated.

Description of Couplings, Fig. 75.—The two couplings, 1, 1, are exactly alike, and an air-tight joint is formed by means of the rubber packing-rings 3, which rings face against each other when the couplings are united. The air-pressure in the coupling tends to force these rings towards one another, so that the joint becomes tighter with increase of pressure. The tendency of the air-pressure in the couplings is also to force them apart in a direction at a right angle to the line of the india-rubber hose-pipe 7, and consequently, the greater the pressure the more firmly are the couplings held together by the projecting piece of each coupling, which fits in a corresponding groove of the other coupling.

No damage is done if the couplings be drawn apart forcibly by the separation of the train, as the rubber rings 3 are forced into their respective couplings far enough to permit the projections to disengage from their grooves.

These couplings are united by placing them together, with one at right angles to the other, and then turning the projection of the one into the groove of the other.

DRIVER'S BRAKE-VALVE.

Air passes from the main reservoir into the chamber A, Fig. 76, in which is the rotating valve 4, seated upwards by means of a spring 8. When the handle is in the proper position for filling the brake-pipe, the air

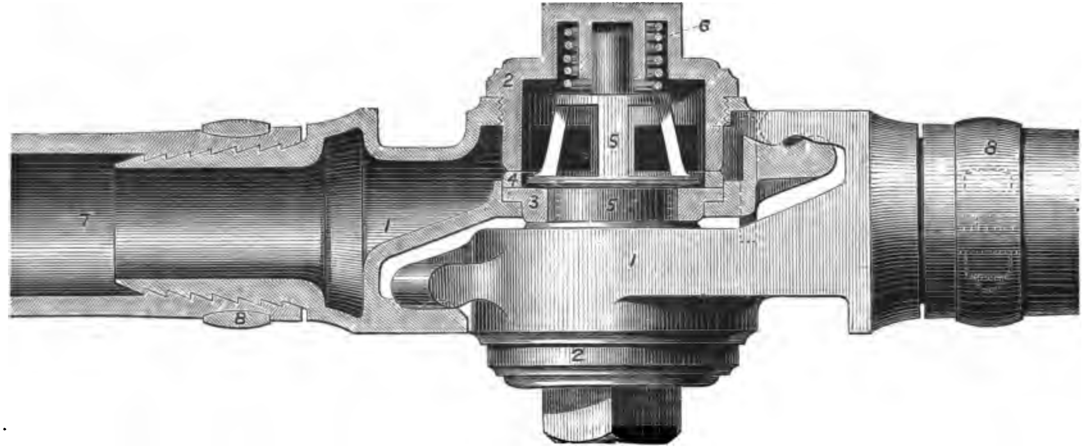


Fig. 75.—Westinghouse Automatic Brake—Couplings.

passes through a port in the valve 4 into the chamber B and the brake-pipe, the discharge-valve 3 being held to its seat by means of the spring 7. The spring 7 is held down by the handle 2, the rotary motion of which regulates the amount of pressure upon the spring by the coarse screw. The valve 3 and the rotating valve 4 turn with the handle 2. When the handle 2 is in its ordinary position during running, a passage of $\frac{1}{8}$ inch in diameter is open between the chamber C, in which is seated the small valve 6, and the chamber B, this opening being for the purpose of maintaining the pressure in the brake-pipe. The spring 9, which holds this valve to its seat, has a pressure of about fifteen pounds, so that the pressure in the main reservoir must always exceed that in the

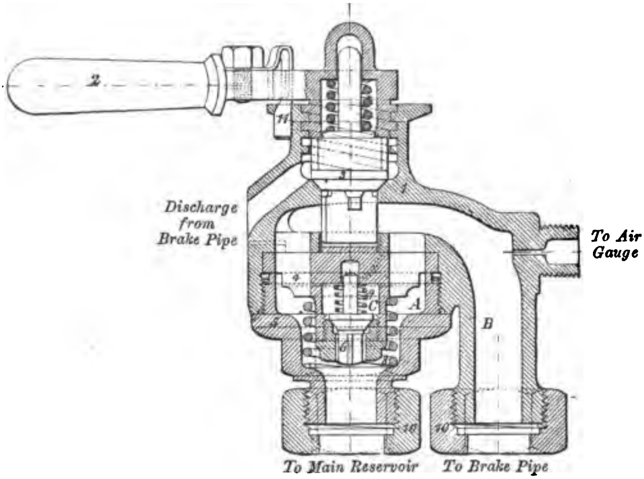


Fig. 76.—Westinghouse Automatic Brake—Driver's Brake-Valve.

brake-pipe by at least fifteen pounds. When the excess becomes greater than that amount, additional air passes into the brake-pipe until the spring is again able to close the valve 6.

To apply the brake the handle 2 is turned to the right. This relieves the pressure upon the spring 7 and allows the discharge-valve 3 to be raised from its seat by the pressure of air in the chamber B, thus discharging the air from the brake-pipe and applying the brake. At the same time the valve 4 rotates with the handle, and this motion closes all communication between the chamber A and the chamber B.

If the handle 2 is turned to its farthest position to the right, the valve 3 gives a full opening to the discharge of air from the brake-pipe, and the brakes are applied immediately with full force, as in cases of emergency.

To release the brake, the handle 2 is turned to the farthest position to the left. This closes the discharge-valve 3 by compressing the spring 7, and at the same time causes the valve 4 to turn to a position in which there is a free opening between the chamber A and the chamber B. This allows the brake-pipe to be recharged from the air in the main reservoir, and the brakes to be released. As soon as the brake-pipe is recharged the handle 2 is turned slightly to the right, or its normal position, closing the full opening between the chambers A and B, but leaving open the $\frac{1}{8}$-inch passage from the chamber C to the chamber B.

The object of allowing any excess of pressure created in the main reservoir to pass into the brake-pipe only through the $\frac{1}{8}$-inch passage is to provide for any gradual leakage, and at the same time to prevent the total escape of the air in the main reservoir in case of any sudden rupture of the pipe.

This valve is very simple in its operation, and admits of the most perfect gradation of the force with which the brakes are applied, irrespective of the number of vehicles in the train.

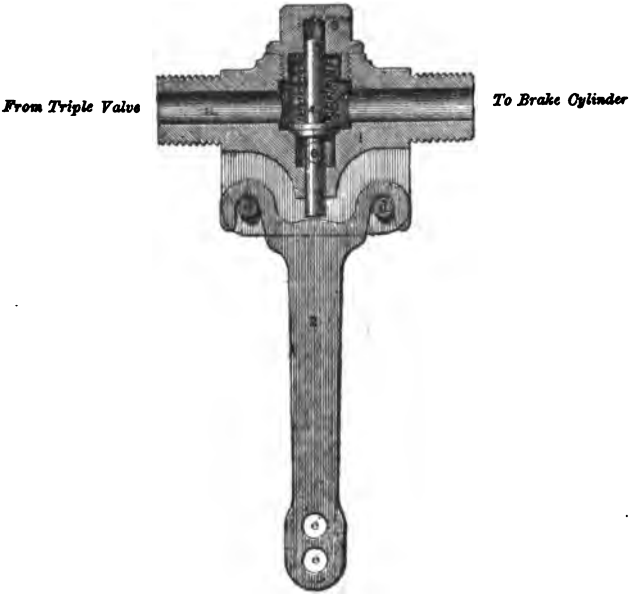


Fig. 77.—Westinghouse Automatic Brake—Release-Valve.

RELEASE-VALVE.

The brake release-valve, which is illustrated in Fig. 77, is fitted on every vehicle, for the purpose of releasing the brake, if applied when an engine is not attached. One end screws into the brake-cylinder, and the other into the pipe leading from the triple-valve. A wire or chain is attached to the handle, which may be pulled from either side of carriage. This lifts the valve 4, and the air passes from the cylinder by the passage to the atmosphere, through the hole 6. On releasing the handle, the valve 4 is reseated by the spring 5.

CHAPTER XIV.

THE RELATIVE CAPACITIES OF BRAKES.

The comparative merits of continuous brakes was unknown until the celebrated trials were made at Newark in 1875, and the information then gained of the relative efficiency of the various systems was most valuable.

The annexed Tables, Nos. I., II., III., IV., contain all the data to show what was done by each brake regarded as a train-stopper. The weight of the engines and tenders and trains are given separately and combined. These are followed by a statement of the observed times in seconds occupied in running successive distances 800 feet; the last column of seconds giving the figures from which the speed is deduced. It will be seen that, in a great many cases, the last section of 800 feet was run in 11 seconds, which corresponds to a speed of 49·5 miles per hour. Train after train attained this speed, but failed to exceed it.

It was the intention of the Railway Commissioners to test the brakes when the speed reached 60 miles an hour, but they evidently did not know anything about the capabilities of engines in this country, although these were, and are, the very best in the world. Every possible effort was made to reach a

cay, June, 1875.

N.	Work in foot-tons per second performed by brake.	Reduced distance for fifty miles an hour.	REMARKS.
	ft.-tons.	feet.	
T. W.	315·6	2437	In A experiment only the ordinary hand brakes on tender and in vans were used.
ian.	188·7	3269	
uth Co	174·2	3779	
rthern.	243·1	3663	
nd.	164·4	3330	
T. W.	640·	1412*	In B experiments, tender brake, van brake, and continuous brake applied by guards on flag or cord signal. * Chain parted at seventh carriage from engine. The hind portion came to a stand 169ft. in the rear of the first portion. The hook of the draw-bar was found 554ft. back from the last carriage of first portion of train. † Engine had to be stopped and fire drawn for want of feed on run. Brake fitted to eight carriages only.
ian.	351·	2178	
uth Co	393·9	2033	
Y.	6C8·4	1079	
rthern.	700·0	1308	
nd.	—	—†	
nd.	963·3	813	
nd.	937·2	899	
nd.	506·4	1660	
ian.	491·5	1635	In D experiments, all available means of stopping, except the use of sand, were employed. North-Eastern engine.
uth Co	531·0	1601	
Y.	452·1	1468	
rthern.	748·1	1477	
7. R.	634·2	1458	
nd.	964·1	844	
nd.	782·0	1120	
nd.	565·0	1488	

dor	6235	676·5	1158	In E experiments, every available means of stopping to be used, including sand.
Sc	6728	539·6	1579	
and	2866	584·8	1141	
and	2440	808·7	1078	North-Eastern Engine.
dla	8081	723·2	1083	
No	5738	786·9	1118	
No	7750	807·0	1131	
d N	7375	781·9	1087	
dla	8319	1017·7	776	
d N dor	0812	840·8	1057	In F experiments, guard signals driver from rear to put on continuous brake.
Sc	4216	677·0	1076	
and	6728	539·6	1547	
dla	2865	476·5	1347	
dla	7347	642·5	1386	
No	5935	724·	1147	
	5738	414·2	2543	Signal given from van at rear. Cord did not work. Experiment unsatisfactory.
No	6408	669·6	1370	Cord specially adjusted in this experiment. Signal given from fourth vehicle from rear.
d N and	2680	704·4	960	In G experiments, guard puts on brake without signalling to driver, who applies no brake.
dor	1407	368·0	1560	
No	464	765·0	1599	
dla	5738	677·	1118	
	236	569·	1660	
dla	1104	694·0	900	In series G and 3rd of supplementary, passenger puts on brake. Steam is kept on till driver feels resistance of brake.
dla	097	1004·5	753	Guard applies all brakes, engine and tender included.
				In I series of experiments, only engine and tender brakes to be used.
d N dla	328	152·4	4289	No brake on engine.
	910	187·1	2961	
				In experiments No. 4 supplementary, the train was parted in two by a slip coupling, and the figures refer to the rear or slipped portion of the train.
dor	049	282·4	1623	Coupling slipped on third vehicle from engine. Hand brakes in vans at tail of train not used.
No	627	176·6	3763	Slipped at end of second vehicle from engine. Hand brake put on by guards.
dla	529	698·7	793	Slipped at rear of third vehicle from engine.

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ine and Tender only.

TRA		REMARKS.
nd No orth E eat No		In A series of experiments no brakes of any kind were used.
nd No Easte eat No		In B series of experiments only hand brake on tender was used.
nd No		Tender brake and engine reversed with full steam.
rth E		Vacuum brake applied to engine and tender.
eat No		Tender brake and engine reversed with full steam.

RAKE COMPETITION. TABLE IV.—*Experiments with a onsisting of Six Midland Vans fitted with Hand Brakes.*

	hour.	Distance in feet.	Time in seconds.	REMARKS.
estern ast.	½	679	20	Hand brakes put on as quickly as possible so as just not to skid wheels. Leading pair of fifth van skidded for a few feet. Three seconds required to put brake on.
draulic		577	16½	Brake to be put on as hard as possible. Only four vans skidded. Time required to skid, eight seconds.

speed of 60 miles an hour in the course of 3½ miles; but, with the weight drawn by each engine, it was found to be an impossible feat. About this fact, future engineers and fast-flyers may have something to talk. In almost every instance the drivers, before reaching the last 800 feet, worked their engines very well, but they no sooner entered the last length than, without easing the regulator, they put their hand-lever over and choked the exhaust-ports with steam. The speed was thus occasionally reduced, because the back-pressure was increased.

The simple statement of the speeds and distances run after the application of the brake, conveys very little information; and we must, therefore, draw particular attention to the last three columns, as they are instructive, and contain the data which are required to enable us to determine which is the most efficient brake, without consideration for the mechanical peculiarities or the cost of construction. The last item is not in the question where human life is at stake. At whatever cost, to save life, suffering, and misery has always been, and will be, looked upon as a praiseworthy object.

The system adopted in calculating the last three columns of figures may be briefly explained. During the time a train is acquiring a given velocity, work is being stored up in it, and all this work must be expended on something and in some way before the train can be brought to a state of rest. The amount of work stored up depends on the weight and the velocity of the whole moving mass of the train, and is in all cases equivalent to that which would be expended in lifting the whole train—engine, tender, and all—to the height from which the mass would have to fall to acquire the given velocity. This height is expressed by the formula $\frac{v^2}{2g}$, in which v represents the speed or velocity in feet per second, g represents the action of gravity, expressed by 32·2. The formula reads thus: —If the velocity of a train in feet per second be squared, that is, multiplied by itself, and the square be divided by 64·4—action of gravity—the quotient is the height in feet from which the moving body must fall to acquire the required velocity. Suppose, for example, that the speed of a train is 88 feet per second, or, what is the same, 60 miles an hour; then 88 squared and divided by 64·4 gives 120·25 feet as the height due to the given speed; and the work stored in the train running at 60 miles an hour will obviously be great enough, if the motion could suddenly be diverted to a vertical direction upwards, to carry the train up in the air, against the action of gravity, to a height of 120·25 feet. The whole of the work stored in the train may be reduced to an equivalent representing a gross weight in tons lifted to a height of 1 foot. This is obtained by multiplying the whole weight of the train by the height due to the velocity, an operation which is expressed by the formula $\frac{w\,v^2}{2g}$, in which w is the weight of the body in tons. This calculation has been made for each experiment recorded in the Table in the third last column.

Now, before a train can be brought to rest, the work put into it, and there accumulated while its velocity was being augmented, calculated as above explained, must be taken out of it; and this constitutes one element in estimating the power of a brake with a moderate increase in the velocity of a train. Since the work thus accumulated in the train increases as the square of the speed, the work to be done by the brake in undoing the work in the train is greatly augmented. For example, the London and Brighton train, No. 16, when running at 52 miles an hour, had as much work stored up in it as would suffice to lift 18,319 tons 1 foot high, that is, 18,319 foot-tons; but the same train when running at 49·5 miles an hour had only 16,728 foot-tons of work stored in it. As, then, the stored work has to be taken out by the brake, no better measure of the work actually done by each brake can be found than that just given. The Table shows on inspection the actual work done in foot-tons by each system in each run. But this statement in foot-tons is by itself incomplete, since it shows only the total work done, and takes no account of the *time* in which it is done. So, of two brakes doing precisely the same amount of work, one might be twice as long in doing the work as the other, and consequently it would really be only half as efficient. The second last column of figures is, therefore, supplied, which shows not only the whole work in foot-tons, but the work done in *foot-tons per second;* and this column contains all that is necessary for forming an opinion as to the merits of a brake. The figures therein contained show the efficiency of each brake, and the deductions which may be drawn from it are sufficiently remarkable. Thus, for example, we find from numbers 17, 18, and 19, that while a brake—Fay's brake—in one instance did work to the amount of 452·1 foot-tons in a second, another —Smith's—did 748·1 foot-tons, and a third—Clark's

—did 634·2 foot-tons per second. These are, then, the standard data by which to compare the merits of various brakes.

But even now the facts are not all laid bare, and so another column, the last, is added, showing the distance to which all the trains would have run had the speed in each example been 50 miles an hour when the brake was applied. It may be well to explain that the distance which a train, or any other moving body, traverses against a constant retarding force varies as the square of the velocity, whilst the time occupied in traversing these distances varies only as the velocities; that is, for instance, if a train running at 10 miles an hour be brought to rest in the course of 100 feet in 22 seconds; then, under the same conditions of retardation, if the train be running at a speed of 20 miles an hour, it would traverse 400 feet, and would occupy 44 seconds in being brought to rest. On this principle the contents of the last column have been calculated.

Now, in all the brake trials recorded in the Table, the whole of the work of retardation is credited to the brake, and it is certain that this involves some error, because there is the friction of the journals, the resistance of the road, and that of the air, in opposition. As the error is very trifling, we may pass that by, and go on to explain the Table, and learn something from it. It will be seen that, so far as the action of the brake-blocks alone is concerned, the work done by all the brakes appears to have been about the same. But, notwithstanding this fact, the Table shows that some brakes were better than others; and it is important to show how these differences are got at. Thus, for example, in the experiment No. 37, the Westinghouse automatic-brake developed a resistance of 724· foot-tons per second, and No. 39, Smith's vacuum-brake, developed 669·6 foot-tons per second.

In an experiment made to test the time required to apply the blocks, the train, in the case of the automatic-brake, being at rest, all the brakes were applied simultaneously, in not more than 3 seconds after the valve was opened; whilst the time required to apply the blocks by the vacuum-brake, varied from 7 seconds to 18 seconds. The train fitted with the automatic-brake was stopped in 18 seconds, and the train fitted with the vacuum-brake in 24·5 seconds. Taking 3 seconds as the time required to put on the brake in No. 37, the whole time the brake was in action was but 15 seconds; and if we strike an average, and say that the whole time required to apply all the blocks in No. 39 was 12·5 seconds, then the time the brake was really in action was but 12 seconds. It would appear from this, at first sight, that the train No. 39, which took most time to pull up, was fitted with the best brake, provided it could be got into action more quickly. But, in case of accident, it is obvious that the brake which is most quickly applied by the driver is the most useful. In the case of No. 9, applied by hand by the guard with a continuous screw, 608·4 foot-tons of work per second was done; and this is below the result obtained either by the automatic air-brake, or by the vacuum-brake. There is here a falling off in efficiency, and it is due first to the time lost in getting the blocks into action, and secondly to the power adopted for applying the brake. The automatic air-brake, as already described, is applied by compressed-air of from 80 lbs. to 100 lbs. pressure per square inch.

The vacuum is applied as a force against the ordinary pressure of the atmosphere; and the screw-brake is applied by manual force at the ordinary hand-wheel in the guard's van.

Another point worth consideration is that the mere extension of a continuous brake throughout a train may, under certain circumstances, be of no possible utility.

CHAPTER XV.

SUMMARY AND CONCLUDING REMARKS.

THE Board of Trade, guided by ample experience, have issued a circular in which they have laid great stress on the importance of all trains being fitted with continuous brakes, to comply with the following conditions. The brakes must be capable of stopping a train on a level, within 275 yards, from a speed of 50 miles an hour. They must be instantaneous in their action. They must be capable of being applied without difficulty by the engine-driver and the guards.

In case of accident they are to be instantaneously self-acting. The brakes are to be put "on" and taken "off" with facility, on the engine and on every vehicle in the train. The brakes are to be regularly used in daily working. The material is to be of a durable character, so as to be easily maintained and kept in order. The public and railway-men will cordially agree with this order.

Independently of the conditions laid down by the Board of Trade, there are certain characteristics which it is desirable to secure and which may be briefly summed up as follows: for instance, it is important that the brakes should act simultaneously upon each wheel of the train in order to secure the best results in stopping, with the least strain upon the draw-bars, and if the brakes are to act automatically upon each portion of the train in case of a separation of the couplings, it is obvious that the engine, as well as the tender, and every other vehicle should have its own store of power to be brought into action when required.

The drivers who stop and slow trains for ordinary purposes should be able to apply the brakes with whatever force they think best, and the brakes should remain on until released, otherwise a severed portion of a train might cause an accident by moving on an incline. The engine or any carriage should be capable of being easily detached without applying the brakes, and the store of power should remain available on the detached portion of a train, so that it may at any time be in the power of the guard, in any case of emergency, independently to apply the brakes of the severed portion.

Damage during an accident to the brake or any one carriage should not destroy the efficiency of the brakes on other carriages. On many railways, portions of trains are purposely slipped, and it should be possible to separate the train without applying the brakes, at the same time leaving the brake-force capable of being brought into action at the pleasure of the driver and guards on both portions of the train.

It sometimes happens that the brakes are required to be applied several times within a few hundred yards, or to control trains in the descent of long inclines. The brake-force should not be exhausted by such frequent applications.

Within certain limits the distance which can be allowed between the brake-blocks and the tyres of the wheels when the brake is not in operation, without at the same time diminishing the pressure which can be brought to bear by means of the pistons on the blocks when the brakes are applied, is a very important consideration.

If the brake-blocks cannot be moved well away from the wheels, they may be constantly rubbing, causing great waste of locomotive power in the running of the trains.

Let us now notice, first, the non-automatic air-brake, which is clearly illustrated by a simple drawing, Fig. 78. Under each carriage is a cylinder connected with the main pipe, A. This is a simple and cheap arrangement, but it does not fulfil the requirements of the Board of Trade, although two schemes have been invented to make this brake automatic in its action. One is shown by Fig. 79. It consists of a brake-cylinder and reservoir, E, in connection with the brake-pipe, A. The pressure of air in the brake-pipe moves the piston into the position shown, so as to clear the passage leading to the reservoir, which thus becomes charged with compressed-air. A check-valve, K, prevents any return of air from the reservoir to the brake-pipe.

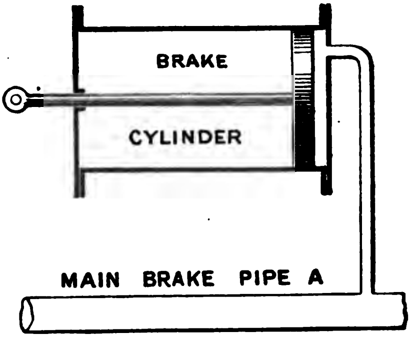


Fig. 78.—Non-Automatic Brake.

To apply the brakes, air from the brake-pipe on one side of the piston is withdrawn from the pipe running the length of the train, and the pressure in the reservoir on the other side forces out the piston and applies the brake. If any of the carriages parted asunder, the compressed-air would rush out of the main pipe and the reduction of air would cause the superior or higher pressure in the reservoir to set the brakes into action. This brake, therefore, is in that particular feature automatic. At first sight, this appears simple and satisfactory, but on further examination we shall find several objections which render it difficult to work in practice. First, to apply the brakes fully, all the air in the brake-pipe and the cylinder on each carriage has to be exhausted at the engine. Hence an enormous waste of air, to replace which, for frequent stops, a powerful high-speed air-pump would be required. Secondly, owing to the large volume of air from all the brake-cylinders having to be discharged at the engine and through a long pipe of comparatively small diameter,

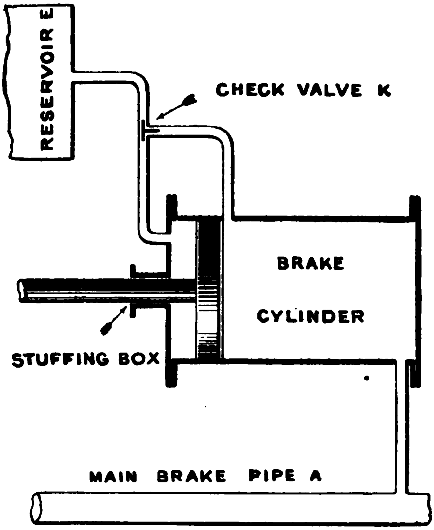


Fig. 79.—Automatic Air-Brake.

this brake is necessarily very slow in its action. Thirdly, air being admitted to both sides of the piston, the piston-rod has to be packed. So long as this plan only concerns the brake on an engine, where the driver can keep it in order, it is not of much consequence; but when applied to the whole of the carriage-stock of a large railway company, it becomes a most important matter. For, in addition to the friction of the piston-rods, these packings would be constantly leaking and thereby cause a further waste of air. This increases the first objection. Keeping to the principle of maintaining air-pressures on both sides of the piston, only the second objection of slow action has been, to some extent, overcome. This is done by attaching to each brake-cylinder, a valve of such construction that a reduction of pressure in the brake-pipe allows air from each cylinder to exhaust separately under every vehicle, direct into the atmosphere, without having to travel all the way to the engine, and the brakes are applied as before. This arrangement is shown in principle in Fig. 80. Air from the brake-pipe opens a small valve in the centre of the diaphragm, and fills the cylinder and reservoir. To apply the brakes, a reduction of pressure is made in the brake-pipe and above the diaphragm by the driver or the guard; the pressure below raises the diaphragm-valve, and the air from the cylinder exhausts into the atmosphere. This certainly diminishes the slow action of this class of brake, but the two objections, namely, enormous waste of air and piston-rod packing, can never be overcome in this way, and makes the whole impracticable. The question has been solved in another way, shown in Fig. 81, the Westinghouse automatic-brake.

In this system, a small piston and slide-valve—generally known as the triple-valve—is placed between the brake-pipe reservoir and cylinder. Air from the brake-pipe pushes the piston into the position shown, and feeds through a small hole past the piston into the reservoir. This piston carries with it a slide-valve, which covers the port leading to the brake-cylinder. To apply the brakes, the brake-pipe pressure below the piston is reduced by the driver or guard operating his brake-valve, and the piston and slide-valve are instantly lowered by the higher pressure

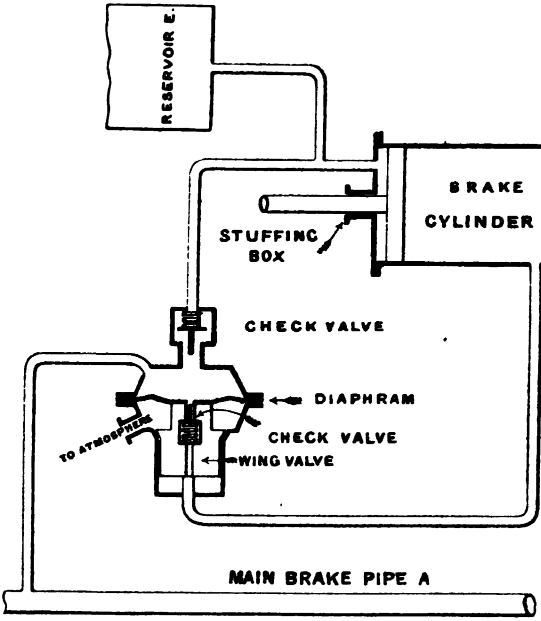


Fig. 80.—Automatic-Brake.

above, thus uncovering the port and allowing part of the air in the reservoir to flow into the brake-cylinder. To release the brakes, air from the main reservoir on the engine restores the pressure in the brake-pipe, at the same time lifting the piston and slide-valve into the position shown, and allowing the air from the brake-cylinder to exhaust into the atmosphere. The advantages here are: first, by storing the air in a separate reservoir, and afterwards applying it to one side only of the piston, a packing for the piston-rod, with its inconvenience and expense, is avoided; secondly, since the brakes can be applied with full force by a reduction of one-seventh of the pressure in the brake-pipe only, very great economy of air, combined with an almost instantaneous application of the brake on long trains, is the result.

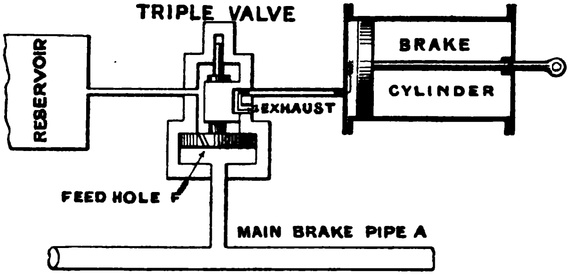


Fig. 81.—Westinghouse Automatic Brake.

That this is so may be seen by a study of the following figures:—Suppose the brake-cylinder in Fig. 79 to be 8 inches in diameter and 12 inches long, the stroke of the piston, on an average, 6 inches, the brake-pipe 1 inch in diameter, the auxiliary reservoir of 1,800 cubic inches capacity, and the apparatus fitted to a train of fifteen vehicles, each 30 feet in length. Capacity of one brake-cylinder = 600 cubic inches; capacity of brake-pipe on one carriage = 284 cubic inches. To apply the brake fully, as arranged in Fig. 79, there must be discharged on each vehicle 884 cubic inches of air. Comparing this with the Westinghouse system, shown in Fig. 81, the brakes will be fully applied by discharging only 40 cubic inches, or one-seventh of the air in the brake-pipe. Taking an 8-inch cylinder with 6 inches of stroke, when the brake is fully applied, the reservoir holding 1,800 cubic inches and the cylinder 300 cubic inches, the air when thrown into one expands into 2,100 cubic inches of space; thereby reducing the pressure to six-sevenths of its original amount; to effect this it is only necessary to reduce the brake-pipe pressure one-seventh. For fifteen vehicles, then, to apply the brakes fully, the relative proportions will be:—Fig. 79, 13,260 cubic inches; Fig. 81, 780 cubic inches. This explains the reason of slow action.

Now for the quantity of air used in the two systems. Taking Fig. 79 and Fig. 80: volume of cylinder = 600 cubic inches; volume of brake-pipe = 284 cubic inches; total 884 cubic inches. Fig. 81 for the Westinghouse brake: $\frac{1}{2}$ volume of cylinder = 300 cubic inches; $\frac{1}{7}$ volume of brake-pipe = 40 cubic inches; total 340 cubic inches. In either of the systems shown in Figs. 79 and 80, the air used amounts to fully 2½ times that required in the case of Fig. 81. For the full application of the brakes, as in Fig. 80, the amount of air to be discharged is considerably less than that in Fig. 79. The volume of the brake-pipe is 284 cubic inches, which must be discharged, against 40 cubic inches in the case of Fig. 81, so that Fig. 80 has to discharge seven times more air than the Westinghouse, to apply it with full force.

Resuming what has been said, it is seen that Steel recommends the employment of pressure on both sides of the piston, and Westinghouse the use of a separate reservoir, and a triple-valve. In the former system, stuffing-boxes are necessary; but it has long since been recognised that these are to be avoided in air-brakes; and also that brakes constructed on the Steel principle cannot be successfully used without a valve somewhat similar to the Westinghouse triple-valve. Even then, the brake is slow in its action, and the waste of air is very considerable. Therefore, all things considered, it may now be accepted that the principle adopted by Mr. Westinghouse is correct for pressure-brakes.

Two principles, or rather two systems, of vacuum-brake prevail: 1st. The use of vacuum on both sides of the piston; 2nd. A store of vacuum maintained separate from the brake-cylinder by one or more valves.

The question is similar to that of pressure, and this is clear because, in both cases, pistons are moved by air-pressure. The same arguments are applicable, and therefore a vacuum-brake with a separate reservoir and a valve between it and the brake-cylinder, will give better results than a brake with a vacuum on both sides of the piston.

When we come to consider what has been done in automatic vacuum-brakes, however, we see that very defective contrivances are now proposed and recommended by the patentees in the field.

In describing these, we have already pointed out that this brake must always be fully on or fully off, because the valve, A, must be over on one side or the other. This is sufficient to show that the valves used are so defective in principle that they cannot be called "practical."

Besides, the number of applications of this contrivance is as yet so small that it cannot be said to have entered into practical life; and we are sure that a great extension of this principle would at once bring to light its great defects and its inferiority as a trustworthy mechanical contrivance.

As to the other automatic vacuum-brakes described, they must also be considered as imperfect, except, perhaps, the Eames brake, which is much the best. But the whole brake has been spoiled by adding to it a second line of pipe putting all the brake-cylinders into communication with one another. Most of the advantages of automatic action are thereby lost, and, as before said, we do not think that this brake is much safer than a simple vacuum-brake.

If the plain pipe in the Eames brake is done away with, there remains a complete automatic vacuum-brake, which might give a fair brake if the reservoirs on the carriages were made large enough.

It then resembles closely the Westinghouse brake, with the exception of the use of vacuum instead of pressure. The action of the valve is identical with that of the Westinghouse single valve, but it is by no means simpler. This apparatus is most fitting for a comparison of automatic vacuum *versus* automatic pressure. The comparison must have relation to simplicity, efficiency, bulk, and weight.

As to *simplicity*, the close study of the two apparatus shows that the Eames brake has no advantage over the

Westinghouse brake. On the contrary, the valve used by Eames is at least as complicated as the Westinghouse valve, and is not so reliable and durable, because it contains a flexible diaphragm which is out of sight and will fail.

It must be remembered that Westinghouse used diaphragm-valves as early as in 1873, and found that they did not stand well in daily use. He therefore adopted a small piston and slide-valve instead of a diaphragm, and he finds that they answer the purpose much better.

We do not think that the vacuum-valves will meet with a different fate, and if ever automatic vacuum-brakes are used in the future, we are convinced that piston-valves will do better than diaphragm-valves. Whenever it is tried to make a suitable valve for automatic vacuum-brakes, it will be found to be anything but an easy matter. It is beyond doubt that such valves will give great trouble from freezing, because the exhaust of air and return of moisture are much more serious with automatic vacuum-brakes than with pressure-brakes.

It is certain that automatic vacuum-brakes cannot be used with the necessary degree of efficiency without a valve at least as complicated as the triple-valve, and they have, therefore, no advantage on that score.

As to *efficiency,* when describing the Hardy automatic brake we gave a calculation as to the size of reservoir that would be required to bring the efficiency of that automatic vacuum-brake somewhere near to that of the Westinghouse brake, and we found that the reservoirs on the carriages would have to be about 20 times as large as for the Westinghouse brake. This calculation holds good also for the Eames brake.

As to *bulk* and *weight*, the foregoing remark illustrates sufficiently the impracticability of such apparatus. But, all things put together, we think that the following remark is not without importance.

Suppose that it is possible to construct an automatic vacuum-brake, which performs exactly as much as the Westinghouse automatic brake. We then ask, where is the advantage to use vacuum rather than pressure?

What is the advantage of using eight times larger pistons and twenty times larger reservoirs of great bulk and enormous weight?

The general tendency of engineering science is towards the use of high pressure, and not towards the use of vacuum; and there is no reason why this rule should not apply to continuous brakes.

The following Table is of interest in comparing the total weight of the brake apparatus (foundation brakes included) in the case of the Westinghouse automatic brake, and that of the Smith-Hardy vacuum-brake.

	Westinghouse automatic.		Smith-Hardy vacuum.	
	Engine & Tender.	One Carriage.	Engine & Tender.	One Carriage.
	lbs.	lbs.	lbs.	lbs.
Weight of the foundation-brakes, manufactured by the Railway Company, according to the designs of the Brake Company .	231·7	1080	359·6	2171·5
Weight of the apparatus supplied by the Brake Company	440·9	198·4	376·6	233·6
Total weight of the apparatus, foundation-brake included	2758	1100	3963·8	2405·2
Total weight of the apparatus for the whole train . . .	30293·5		64121·5	

These weights were carefully noted by the Paris, Lyons, and Mediterranean Railway Company, who fitted two trains exactly alike with these two brakes. The trains consisted of one engine, one tender, and 25 carriages. The Table shows that the vacuum-brake is nearly two and a quarter times as heavy as the Westinghouse brake.

In regard to the automatic vacuum-brake, as used by the Midland Railway Company, which Company is the only one who largely uses an automatic vacuum-brake, we have already pointed out its weak points. We have only to add that the engines and tenders are fitted with powerful steam-brakes; and, from a great many drivers, we know that they depend for stopping their trains more on their steam-brake than on the automatic vacuum-brake. They have told the author repeatedly that they would come daily to grief with the automatic vacuum-brake if they had not the steam-brake to fall back upon. Therefore, the fact that the Midland Company is using an automatic vacuum-brake in daily working, is no proof whatever that such a brake is satisfactory, and we ourselves are convinced that if the Midland Company abolished the use of the steam-brake on their engines, there would be a serious accident in less than a week.

We might mention here that, when reporting on the accident which occurred on the 10th July, 1881, at the Central Station, Manchester, Major Marindin stated:—*that the results of the collision were no worse, was doubtless due to the fact that the driver had at his command an* EFFICIENT *brake.*

We find, in the same report, that the speed of the train was about 6 miles per hour when the brakes were applied, and that the engine was then at a distance of 65 yards from the point of collision. Notwithstanding this, the train struck the standing engine with force sufficient to cause a great amount of damage. This shows that the brake used was very poor indeed, and it is even hardly conceivable that any continuous brake, how ever poor it may be, could not have brought the train to a stand from a speed of 6 miles an hour within a distance of 65 yards. There is only one way to explain this, with the particular form of brake in question, which was the Clayton or Sanders automatic vacuum-brake, provided with leakholes in the brake pistons. The driver most likely applied the brake when approaching Manchester, and, when he had arrived at the spot where the accident occurred, the speed was reduced to about 6 miles per hour. Then all the brake-power on the train had vanished at the very moment that it was most wanted.

A stronger condemnation of the leakhole arrangement cannot be found.

It results from what has been said above, that air-pressure brakes offer great advantages over vacuum apparatus. Air is a most convenient and admirable medium for transmitting the power from one end of the train to the other. It is exceedingly elastic and prompt in its movements. High pressure admits of great power being derived from small surfaces and light fittings. We have already shown that what is called automatic action is an essential condition in a good continuous brake, but its efficiency depends on the method of carrying out this principle. Let us see what is implied in this term, "automatic action." The Board of Trade Returns show, and we know from experience, that the worst class of accidents arise from broken tyres, axles, and rails, and also imperfections in the permanent way. In such cases it has been found, as indeed was only to be expected, that the brake-apparatus itself is the first thing to be damaged in some vehicle, even if the couplings do not separate. It is therefore most important that such injury should lead to the *instant* application of the brake upon the carriage which is partially damaged, as well as upon those which are left undamaged, and this without the intervention of the driver or the guard, who might not become aware of the mishap until too late to prevent its consequences. Under such circumstances, a non-automatic brake becomes inoperative. Even if it had previously been applied it would at once come off, when the damage was done or the couplings were parted, and this would cease to be a brake, to all intents and purposes, just at the very moment when the best brake in the world was required. In like manner, when a train becomes divided from any cause, although the brake work remains uninjured, the brakes must at once apply themselves, and REMAIN APPLIED, on both portions, until taken off by some one in authority, so that, if on an incline, the rear part cannot run back while the men are thinking and employed about the front part. Automatic action implies that the guard can set it in motion, no matter how far he may be from the engine; he may be in the last vehicle, and he can apply it with the same facility as the driver. This feature has been of great service when passengers have been in danger from attempting to enter or leave carriages in motion.

In the remarkable accident in October, 1880, at

Kibworth, when the engine-driver of a fast express was running his train backwards, without knowing it, there is no doubt that a much more serious collision than what happened was arrested by the use of the brake in the guard's van.

The brake which can be most quickly brought into action will stop a train in the shortest time; and a loss of one second in bringing the greatest possible power to bear upon the wheels may result in a terrible calamity. A study of the most fatal accidents shows that they arose from extraordinary causes, which were impossible to foresee, and not from ordinary defects. The causes which lead to these accidents may possibly be repeated, but one thing we have no doubt of, and that is, that accidents will happen again, when the only safeguard will be a powerful instantaneous self-acting brake. We work at a high speed with high-pressure steam, and haul trains of great weight and length, and therefore in case of a mishap a great powerful brake is necessary to pull up in the shortest possible time. It is what is absolutely required in cases of danger, which frequently is not seen until there is not a second to be lost in pulling up.

After impartial consideration of the various continuous brakes, having well weighed their principles and watched them in practice, and knowing, from the foot-plate point of view, what is required of a brake, it is impossible to come to any other conclusion than that the system invented and perfected by Mr. Westinghouse is the one that meets entirely all the requirements of the Board of Trade. It is indisputable that, regarded as a train-stopper, the Westinghouse automatic brake was by far the best brake at the

Newark trials in 1875. There is no oversetting the fact, that since these trials were made, it has been used in all kinds of weather, upon long and short gradients, and made all kinds of stops, sudden or gradual, in competitive experiments with other brakes, and in everyday working. In all instances it has been unrivalled. It has complied with every demand made upon it either by the Board of Trade or by the people. Its superiority is due, first, to the fact that compressed-air is swifter in its action than either ordinary atmospheric air or water; secondly, that, practically, each carriage is independent of the engine, and carries its own store of power; thirdly, its very rapid and simultaneous action enables it to begin work within a second. Finally, there has been no test to which brake-makers thought proper to see it submitted, that it did not encounter, and it has come out of every ordeal successfully.

A most remarkable report was made on the Westinghouse automatic brake in 1879, by one of our greatest railway engineers, Mr. T. E. Harrison, chief engineer of the North Eastern Railway. This report is exceptionally clear and concise, and it is printed in full in the Appendix.

APPENDIX.

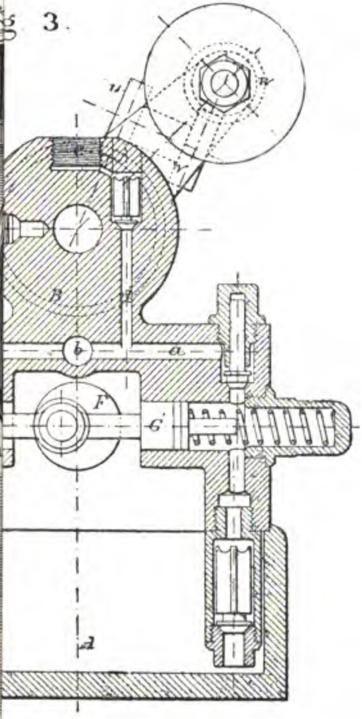
I.—TRAIN SPEED INDICATOR.

At the celebrated brake-trials at Newark, in 1875, it was attempted to obtain trustworthy evidence respecting the retarding force of brakes within given distances, in order to form an estimate of the comparative value of different brakes, by means of an electric apparatus, which recorded the instants at which the experimental trains passed over contact pieces placed on the line of rails, 200 feet apart. This arrangement was well carried out, and every effort was made to secure accuracy. Nevertheless, the system, as a whole, was vastly inferior to that of obtaining a continuous record of speeds by means of a speed-indicator.

The principle of Westinghouse's speed indicator is represented by Figs. 1, 2, 3, 4, Plate IX. The indicator, Figs. 1, 2, and 3, is intended to be fixed in a carriage or a van; and that shown by Fig. 4 is adapted for use on an engine. The principle upon which the apparatus acts consists in controlling the escape of water under pressure by means of a small valve loaded by the action of centrifugal force, the arrangement being such that the higher the speed at which the apparatus is driven, the greater is the pressure exerted by certain revolving weights upon the escape-valve, and the higher therefore is

PLATE IX.

3.



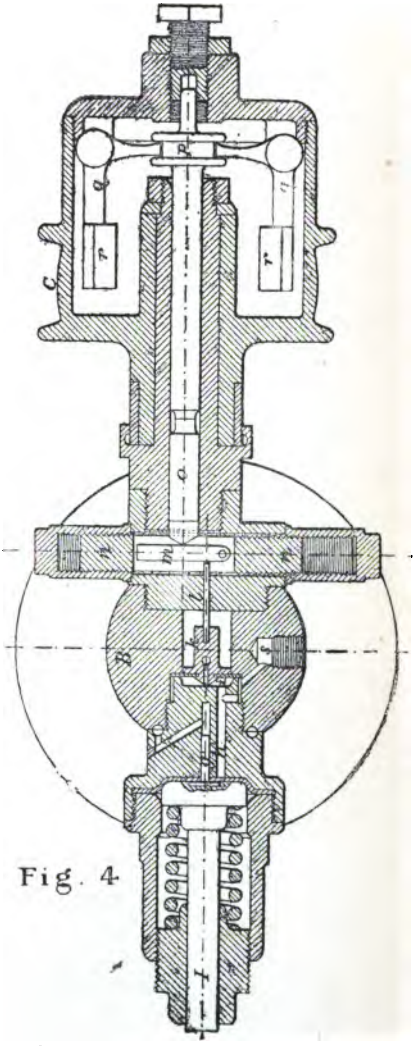


Fig. 4

[*From* "ENGINEERING," *of September* 8, 1876.]

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the pressure maintained within the chamber with which this valve is in communication. The chamber constantly receives a supply of water either from pumps or from the boiler. A pressure-gauge is affixed to the chamber containing the water under pressure, and it affords by its indications information as to the speed at which the apparatus is being driven. Although very simple in principle, much ingenuity has been expended in bringing the apparatus into such a form that its indications shall be trustworthy in practice. Referring to Figs. 2 and 3, it will be seen that the apparatus consists of a base, A, forming a small water-tank, there being bolted down to this base a casting, B, carrying all the rest of the parts. To one side of the casting is fixed a tubular axis, on which is mounted the pulley-casing, C, which is driven by a belt from another pulley on any convenient axle. Care is to be taken that the wheels on this axle are not fitted with brake-blocks. Fixed on the pulley, C, is a pinion, D, which gears into a small spur-wheel, E, mounted on a spindle provided at its other end with a disc-crank, F. From this crank are led off two connecting-rods, G, G, which work small plunger-pumps drawing water from the water-chamber, A. The arrangement is clearly shown in Fig. 3, from which it will be seen that the pistons or short plungers of the pump are forced outwards by springs, so that the connecting-rods work constantly in compression, and the pumps can thus be driven at a high speed without inconvenience.

The two pumps deliver water through channels, *a*, *a*, into the channel *b*, which is fitted with a small spring-loaded relief-valve, as shown in Fig. 2; this valve, when open, allowing any excess of water to escape through the hole, *c*, back into the water-channel, A. Communicating with the passages, *a*, *a*, there is also another channel, *d*, shown in Fig. 3. This passage is fitted with a small check-valve as shown, and through it the water delivered from the pumps can flow up to the socket, *e*, into which the spring accumulator, H, is screwed, as shown in Fig. 2. The construction of this accumulator will be readily understood. It consists of an indiarubber diaphragm, having on its underside a small plunger against which the water acts, whilst on its upper side is another plunger or piston forced downwards by a spiral spring. The lower plunger has a small rod or needle projecting from it, this needle being very slightly tapered, and the water on leaving the accumulator passes down around this needle to a channel, *f f*, leading to a second accumulator, I. This second accumulator is similar to the first, with the exception that it is disposed horizontally instead of vertically, and by the time the water reaches it the pulsations caused by the action of the pumps are entirely destroyed.

In this second accumulator, the water may be considered to be contained at a steady pressure, the amount of this pressure depending upon the arrangements now to be described. When the instrument is fixed on the engine, and the supply of water required is drawn from the boiler instead of being supplied by pumps, the fixed accumulator is dispensed with, one only being employed, as shown in Fig. 4. In this case, the water, instead of entering the accumulator near the periphery, and escaping at the centre around a needle attached to the ram, follows the opposite course, entering through the passage, *f′*, Fig. 4, passing into the accumulator around the needle, *g′*, and escaping through the passage, *h′*, to the regulating escape-valve. Returning to Fig. 2, it will be seen that the water can escape from the second accumulator past the needle, *g*, into the passage, *h*, which is connected by small holes with a recess, *i*, covered by a thin indiarubber diaphragm attached to the relief-valve, *k*. The form of this valve is, as will be seen, such that when raised from its seat, the water flows out through a central opening in the valve into a small chamber, from which it can return into the water-reservoir, A. The regulation of the pressure upon the relief-valve, *k*, is the next point for consideration.

It will be seen from Fig. 4 that the relief-valve, *k*, has attached to it a rod, *l*, which takes a bearing against a small horizontal lever, *m*, as shown. This lever is also pressed at another point by the rod or spindle, *o*, and it will be seen from Fig. 4 that the lever is contained in a recess or mortice cut in a bar, *n*, so that by turning the screwed caps with which the ends of this bar are fitted, the lever can be shifted longitudinally, and the ratio which the pressure exerted by the spindle, *o*, shall bear to that transmitted to the rod, *l*, can thus be adjusted with great delicacy. The spindle, *o*, extends through the tubular axis on the pulley, C; it is mounted, and is provided within that pulley with the grooved collar, *p*, which takes hold of the shorter arms of the two bell-crank levers, *q*, *q*. The other arms of these levers carry small weights, *r*, *r*; and, as the pulley, C, revolves, the centrifugal force developed tends to spread these weights, and thus, through the intervention of the bell-cranks, exerts a pressure longitudinally on the spindle, *o*. But this spindle transmits its pressure through the lever, *m*, and rod, *l*, to the escape-valve, *k*, and thus the pressure with which this valve is loaded depends upon the centrifugal action of the weight, *r*. The whole action of the apparatus will now be clear.

The centrifugal force exerted by the weights, *r*, *r*, will vary as the square of the velocity at which the pulley, C, is driven, and hence the pressure on the escape-valve, *k*, will also vary as the square of the velocity of the pulley, or, what is the same thing, the square of the velocity at which the train is moving. But a constant supply of water is delivered to the accumulator, I, from the pumps—or from the engine-boiler, as the case may be ; and the pressure maintained within this accumulator is controlled by the load on the escape-valve, *k*, hence a pressure-gauge placed in communication with the accumulator, I, will indicate pressures which are proportional to the squares of the speeds of the train.

To connect it with the accumulator, I, the pressure-gauge is screwed into the socket, *s*, and a gauge thus arranged is shown in the perspective view, Fig. 1. From the indications of this gauge, the speed of the train at any instant can be at once ascertained. But beyond this, it was desired, and was found necessary, not only to be able to ascertain the speed of a train at any given instant, but to be able to describe a diagram, like an engine-diagram, recording the decrease of speed after the application of a brake. For this purpose, the apparatus was fitted with attachments for connecting it to a suitable indicator. This indicator is connected at the same point as the pressure-gauge, and its drum is driven as follows:—Referring to the perspective view, Fig. 1, and to Fig. 2, the pulley, c, has fixed to it a short worm, *t*, into gear with which the small worm-wheel, *u*, can be placed. Another worm, *v*, on the same axis as the worm-wheel, *u*, drives another worm-wheel, *w*, and a slow motion is thus given to the disc from which the cord for moving the paper-drum of the indicator is driven. A slow motion is thus obtained for the drum of the indicator. The indicator is similar to the ordinary steam-engine indicator, except that the paper-drum is somewhat larger, its circumference being 12 inches. If, now, the gear for giving motion to the paper-drum be thrown into action at the same time as the brake is applied, the pencil of the indicator being at the same time in contact with the paper, it is evident that as the speed of the train becomes reduced, the pencil of the indicator will fall, and this downward movement, combined with the rotary motion of the drum, will cause an inclined line to be traced on the paper, the height of this line above zero at any given point being a measure of the speed of the train at the corresponding point of its movement. It is evident that the curves drawn by the pencil of the instrument afford the fullest possible information respecting the action of the brake with which the train is fitted. Thus not only do they show the distances run and the mean retarding forces, but they also afford data for calculating the retarding force exerted at each part of the stopping course, and tell whether the brake-power has been applied promptly—as it should be to obtain the best results—or whether it had only come gradually into action, and involved a loss of time at the commencement of the operation, when the train was moving quickly.

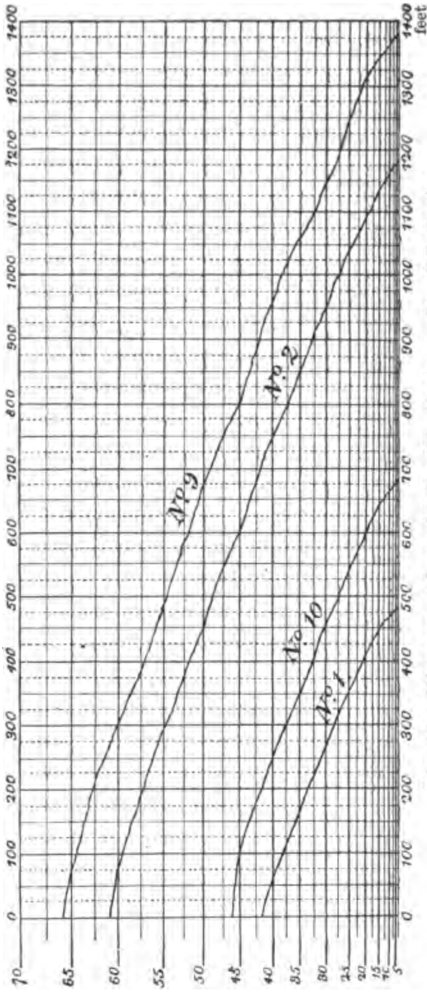


Fig. 82.—Diagrams taken with the Westinghouse Speed-Indicator.

It is hardly necessary to observe that, with a theoretically perfect brake, the retarding force would be constant, and the diagram would be a parallelogram; and that the deviation of the actual diagram from the latter form affords visible evidence of the actual efficiency of a brake. Fig. 82 is a copy of a diagram taken with the apparatus. No. 1 stop: — This shows that the brakes were applied at a speed of 41·5 miles an hour, and stopped in 485 yards. No. 10 stop:—The brakes were applied at 46 miles an hour, and stopped in 680 yards. No. 2 stop:—The brakes were applied at 61 miles an hour, and stopped in 1,185 yards. No. 9 stop:—The brakes were applied at 66 miles an hour, and stopped in 1,380 yards. But, to make any fair comparison between the performances of brakes on different lines, and under different conditions, something more than the maximum speed and the length of stop is absolutely necessary, namely, the weight of the train and the time occupied in stopping.

The comparative experiments that have been made upon different brakes do not afford sufficient data to enable us to give comparative tables, excepting what was done at Newark in 1875. In the experiments which have been made since that time on different brakes, arising from the desire of the Westinghouse Brake Company to meet their rivals in the open field, there has, in many instances, unfortunately, been much difference in the engines and tenders as to size, power, and relative brake-power, some having iron brake-blocks, and some having wooden brake-blocks. Some of the six-wheeled carriages had no brake-blocks on the middle wheels. In some instances the experiments were conducted with trains of eight carriages, such as run on branch lines, which bore no comparison with a heavy freighted train of sixteen or eighteen coaches on the main line. It would suit some systems of brakes to be tested on short trains, such as would require considerable time to bring the blocks into operation on all the carriages of an ordinary express train; but it is on the express trains that prompt action is required. A second or two lost, and all may be lost. A driver may lessen the force of a collision, but that is not sufficient; he must, if possible, avert a collision.

II.—CAPTAIN GALTON'S EXPERIMENTS ON THE ACTION OF BRAKE-BLOCKS.

A NUMBER of important experiments have been made upon the London and Brighton Railway to ascertain, with a single vehicle, the laws governing the action of brake-blocks upon wheels, so as to determine, if possible, the amount of brake-force necessary to produce the best results; also to ascertain the distance within which a single vehicle can be stopped when running at various speeds.

A special brake-van was built by the London and Brighton Railway Company for these experiments. It was attached to the engine, and was run at various speeds, during which various forces were applied to the wheels, and the force of the brake-blocks against the wheels was measured by a self-recording dynamometer.

The experiments were made between Hastings and Brighton, in the presence of Mr. Stroudley, the Locomotive Superintendent of the line, Sir Henry Tyler, Captain Galton, and others. The author was in charge of the engine, "Grosvenor." The results were investigated by Captain Galton, and a paper on the subject was read by him before the Institution of Mechanical Engineers.

The principle of the self-recording dynamometers fixed in the van, is that the force to be measured acts on a piston fitted in a cylinder full of water, and the pressure of the water is measured by a Richards indicator connected by a pipe to the cylinder. Thus, as the drum revolves, diagrams are obtained, giving the force acting on the piston. The advantages of this method are obvious, as the indicator can be placed at any convenient point, and the water, by its inertia, tends to retain the pencil in a position corresponding to the mean force.

The experimental van was fitted with four dynamometers, Nos. 1, 2, 3, 4. Nos. 1 and 2 measure the retarding force which the friction on the brake-blocks exerts on the wheels; No. 3, the force with which the blocks press against the wheels; No. 4, the force required to drag the van. A self-recording speed-indicator, designed by Mr. Westinghouse, and two of Mr. Stroudley's speed-indicators were employed. Of the latter, one was attached to the axle of the braked wheels, the other to the axle which was running free. The difference of these indicators proved whether slipping took place.

There was also a Bourdon gauge attached to the small dynamometer, having the face divided in such a way that the hand indicated the speed in miles per hour. The indicators were all placed on a table in the centre of the van, and the drums were made to revolve by the cords being wound upon pulleys on a shaft, which was turned at a uniform rate by a water-clock. This clock merely consists of a plunger sliding in a cylinder through a water-tight packing, and loaded with a heavy weight. It was wound up by connecting it with the accumulator, and at the beginning of each experiment a small cock was opened, which allowed the water to run out and the weight to fall, which thus turned the indicator at an ascertained uniform speed. Thus, the ordinates of the diagram taken from these indicators, show the various forces, and the abscissæ the distance moved through by the van.

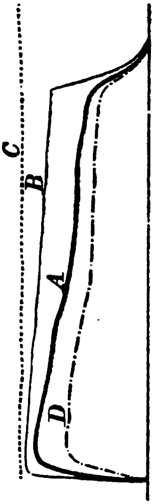
Numerous diagrams were taken by the apparatus, which have been very carefully reduced by Captain Galton. Nine of these are represented at pages 200, 201. The line A indicates the average trangential strain, recorded by indicators 1 and 2; the line B represents the brake-block pressure recorded by indicator No. 3; the line C the speed of the pair of wheels to which blocks were applied, recorded by indicator No. 6; the line C′ the speed of train indicator No. 6; the line D, the traction on the draw-bar recorded by indicator No. 4.

Diagram No. 1.—In this case, the velocity remained nearly constant, varying from 41 miles per hour at the beginning to 40 miles per hour at the end. The air was allowed to escape from the brake-cylinder through the small aperture, and thus the pressure between the blocks and the wheel was diminished. The diagram shows that the friction between the brake-blocks diminished more rapidly than the pressure. The speed indicated by the rotation of the wheels to which brakes were applied was the same as that of the wheels running free.

Diagram No. 2.—This diagram was taken when the van was moving at a speed of 25 miles an hour. By the application of the brake the speed was slackened to 20 miles an hour in 10 seconds, when the wheel skidded, and the experiment closed in 22 seconds, when the speed had been reduced to 17 miles per hour. In this case, the diagram shows no diminution in the rotation of the axle until skidding took place. The velocity of the train was reduced from 25 to 20 miles in 10 seconds, when skidding took place, after which it took 11 seconds to reduce the speed from 20 to 17 miles an hour. Observe the reduction of speed before and after skidding.

Diagram No. 3.—In this experiment, the velocity was 21 miles an hour when the brakes were applied to the wheels; the speed was reduced by the action of the brakes to 18 miles, when the wheels skidded. This diagram shows that the co-efficient of friction between the brake-block and the wheel gradually increased as the speed diminished until the skidding point was reached, and that the tractive force exerted on the draw-bar was suddenly greatly diminished when skidding took place. Observe the pull on the draw-bar before and after skidding.

Diagram No. 4.—In this case the van was detached from the engine by means of a slip-coupling, when travelling at a speed of 40 miles an hour. The pressure of air in the brake-cylinder, and consequently the pressure on the brake-blocks and wheels, remained constant during the experiment. The pressure being greater than that required by the co-efficient of friction between the brake-blocks and wheels, due to the velocity, the friction increased rapidly and caused the wheels to skid immediately. The friction at once decreased, but rose again as the speed diminished, and attained its maximum when the train came to rest. Observe the amount of friction or holding-in power at different speeds. The diagram shows that during the moment of skidding the retarding force increased to an amount much beyond that which prevailed before skidding took place, but immediately after the act of



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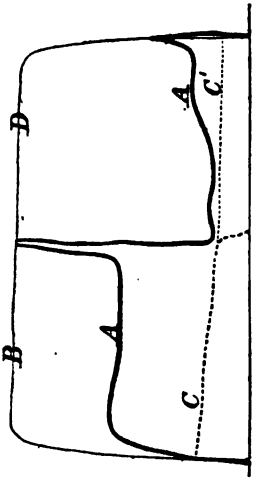

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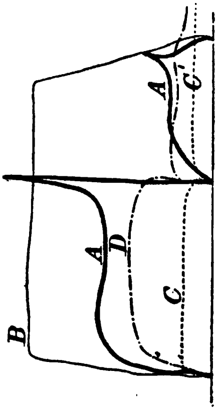

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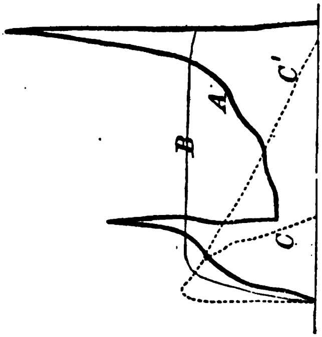

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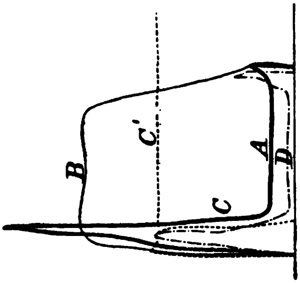

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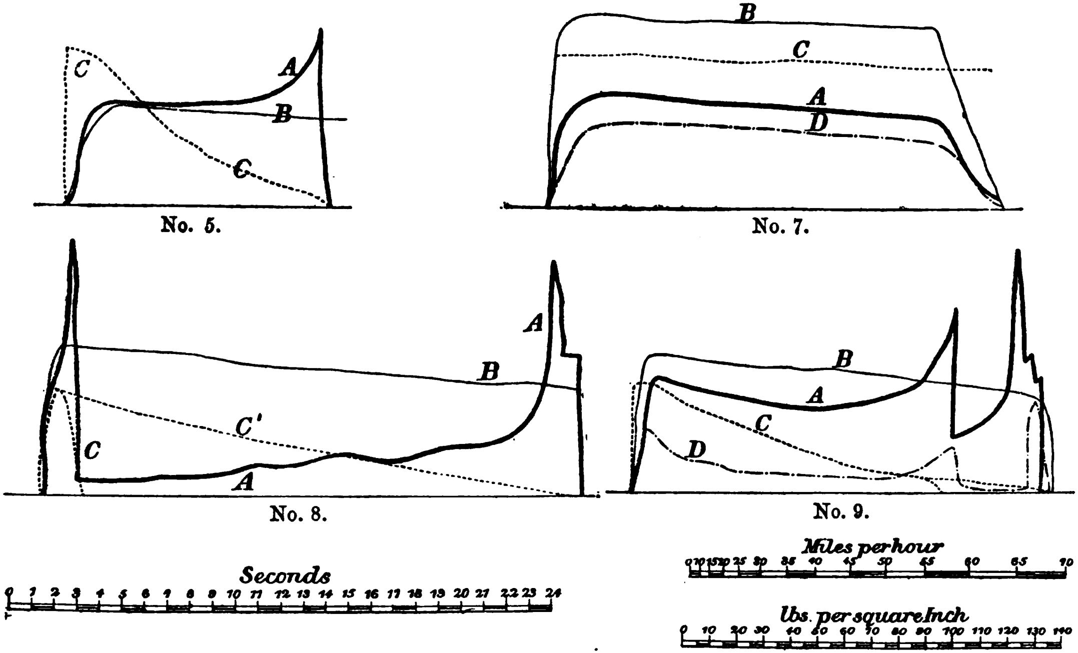

No. 5.

No. 7.

No. 8.

No. 9.

Fig. 83.—Captain Galton's Experiments: Dynametrical Diagrams.

skidding is complete, this pressure falls down again to much below what it was before skidding.

Diagram No. 5.—In this case, also, the van was detached from the engine by means of a slip-coupling when travelling at a speed of 46 miles an hour. The pressure of air, or, what is the same, the force against the wheel, was gradually diminished. At first the friction between the brake-blocks and wheels gradually diminished, but as the speed diminished the friction increased, and brought the van to rest in 12 seconds. Observe the van, in experiment No. 4, was brought to a stand in 12½ seconds from 40 miles an hour; but, in No. 5 trial, the same van with the same weight, and on the same gradient, was brought to rest from 45 miles an hour in 12 seconds.

Diagram No. 6.—In this experiment, the velocity was uniform at 44½ miles an hour. The force skidded the wheels at once. The diagram shows that the coefficient of friction between the brake-block and wheels decreased at once when skidding commenced, and rose at the end of the trial. The tractive force—that is, the pull or force to draw the van—decreased also when skidding commenced.

Diagram No. 7.—In this trial, the speed was 45 miles an hour at the beginning, and was reduced to 42½ miles at the termination of the experiment. The force applied to the wheels was not sufficient to skid them, and the wheels with brakes and those without brakes, as shown by Mr. Stroudley's indicators, revolved at the same rate. The tractive-force on the draw-bar, as shown on this diagram, follows a uniform line. Observe in Diagram No. 6, the force applied to the skidded wheels was much greater than that applied in trial No. 7; but the pulling-up power was much superior with the lesser force (No. 7), which did not skid the wheels.

Diagram No. 8.—In this experiment, the van and the engine were brought to rest by means of the brake from a speed of 40 miles an hour. The force applied to the wheels skidded them at once. The retarding force rose rapidly at the moment of skidding, and then fell. The diagram shows an increase in the co-efficient of friction as the force is applied to the wheels and the speed is reduced. Observe, the friction increased as the speed decreased.

Diagram No. 9.—In this experiment, the van and engine were brought to rest from a speed of 39 miles an hour. The pressure or force against the wheels was gradually diminished, and the diagram shows this:—When the reduction of speed was lowered to the point where the increase in the co-efficient of friction was sufficient to overcome the effect of the diminished speed, the retarding power of the brake was increased and the wheels were skidded. At the moment of skidding the curve rose in a nearly vertical line, thus proving that the co-efficient of friction became very great as the wheel came to rest. Immediately after this rise, the curve fell to a point far below its original position, thus showing a great diminution in the retarding effect of the brake. After this point, the curve rose again while the speed continued to decrease, and again showed that the co-efficient of friction between the rails and the wheels when skidded, increased as the speed decreased. At the moment when the van came to rest, the co-efficient of friction became very great.

We have, therefore, only to deal with two different kinds of retardation:—Friction between the brake-block and the wheel; and the friction between the rail and the wheel. The former is represented by the force applied to the wheels whilst they continue to revolve; the latter is represented by the friction between the rail and the wheel when the wheel skids. We have then to find the co-efficient of friction for each case. The co-efficient of friction is a certain fraction which, when multiplied by the normal pressure, gives the friction.

To solve these questions, Captain Galton first obtained the co-efficient of friction between the brake-blocks and the wheels; secondly, the co-efficient of friction between the wheels and the rails.

Co-efficient of Friction between the Brake-blocks and the Wheels.—It was found that, in proportion as the pressure was increased or diminished, so was the actual friction increased or diminished, and when the pressure against the wheel exceeded the adhesion between the wheel and the rail, added to the force applied to stop the wheel, skidding commenced. As far as could be judged from the experiments, it would appear that whether the speed be high or low, nearly the same amount of fractional resistance is required to produce skidding. In one experiment, where the velocity was 60 miles an hour, the amount of actual frictional resistance which stopped the wheels was about 2,000 lbs., showing an adhesion of 191. In another trial, the speed was 15 miles an hour, and the amount of friction was about 2,160 lbs., exhibiting an adhesion of about 196, and, therefore, the point at which the wheel stops does not vary with the momentum of the wheel, but depends entirely upon the adhesion between the rail and the wheel. Whether the velocity be high or low, the instant or period when the wheel stops and slides, depends upon the force applied to the wheels, the weight upon the wheels, and the state of the rails; and, therefore, with the same weight of train, the same condition of rails, the same amount of brake-friction will stop the wheel at the skidding-point, whatever be the speed.

At a speed of 16 miles an hour, a pressure of 8,169 lbs. applied to the wheels produced a friction of 1,560 lbs.; and at 60 miles an hour a pressure of 13,900 lbs. produced a friction of 1,400 lbs.

It will, therefore, be obvious that it is a difficult matter to find the co-efficient of friction which obtains at different speeds, owing to the time during which the pressure is continued to be applied affecting so largely the quantity of friction produced. In an experiment made with a speed of 55 miles, falling to about 53 miles an hour, a pressure of 35,000 lbs. at the commencement of the trial produced a frictional resistance of 2,040 lbs.; whilst, after 10 seconds, the quantity of frictional resistance had diminished to 1,400 lbs., although the pressure maintained was the same. Again, at a speed of 30 miles an hour, a pressure of 12,000 lbs. produced at first a frictional resistance equivalent to 1,860 lbs.; but, after 10 seconds, this amount had fallen to 1,260 lbs., although the pressure had been raised to 13,440 lbs. It thus appears that the amount of friction is greatly diminished as the surfaces continue in contact. The annexed Table gives a fair approximation to the co-efficient of friction at different speeds, between cast-iron brake-blocks and steel tyres.

CO-EFFICIENTS OF FRICTION. (CAPTAIN GALTON.)

Cast-iron Blocks on Steel Tyres.	Feet per second.	Miles per hour.	At commencement of Experiment.	After 5 seconds.	After 10 seconds.	After 15 seconds.	After 20 seconds.
Just before coming to rest	1 to 3	1 to 2	·250				
When moving at	10	7½	·242				
,, ,, ,,	20	13½	·213	·193			
,, ,, ,,	25	17	·205	·157		·110	
,, ,, ,,	30	20⅗	·182	·152	·133	·116	·099
,, ,, ,,	40	27⅕	·171	·130	·119	·081	·072
,, ,, ,,	45	30⅗	·163	·107	·099		
,, ,, ,,	50	34	·153				
,, ,, ,,	55	37⅓	·152	·096	·083	·069	
,, ,, ,,	60	40⅘	·144	·093			
,, ,, ,,	70	47⅗	·132	·080	·070		
,, ,, ,,	80	54⅖	·106			·045	
,, ,, ,,	88	60	·072	·063	·058		

The Table clearly shows the decrease in the co-efficient of friction dependent on speed, and also the decrease due to the time during which the surfaces were in contact.

A number of experiments were made near Glynde with wrought-iron brake-blocks; but it was evident they were unsuitable, for the jerks produced when they were in contact with the wheels was enough to shake a train to pieces in very little time. So far as the co-efficient is concerned, the result is given in the annexed Table.

FRICTION OF WROUGHT-IRON BLOCKS.

Velocity.		Co-efficient of friction between Wrought-iron Blocks and Steel Tyres.		
Feet per second.	Miles per hour.	At commencement of experiment to 3 seconds.	At from 5 to 7 seconds.	At from 12 to 16 seconds.
70	48	·110		
45	31	·129	11	·099
26	18	·170		

The Effect of Sand.—The presence of sand on the rail largely increased the adhesion both of the blocks and the rails. In the case of wet and greasy rails, sand makes the adhesion about equal to that of a dry rail.

Co-efficient of Friction between the Wheel and the Rail.—When the rotation of the wheel has been stopped by the pressure of the brake-blocks, and the wheel slides on the rail, the retardation of the carriage arises from the friction between the wheel and the rail.

The friction is measured by the force which is exerted in holding the wheel in its fixed position, or by the force required to draw the skidded wheel along the rail over and above that required when the wheel rotates freely, and the experiments showed that these forces were practically the same in amount. The co-efficients of friction are given in the annexed Table.

Friction between Wheel and Rail.

Approximate Speed.		Co-efficient of Friction.	
Feet per second.	Miles per hour.	Steel Tyre on Steel Rails.	Steel Tyre on Iron Rails.
Just coming to rest.		·242	·247
10	7	·088	·095
20	13	·072	·073
40	$27\frac{2}{5}$	·070	
50	34	·065	·070
60	$40\frac{4}{5}$	·057	
70	$51\frac{3}{5}$	·040	·060
80	$54\frac{3}{4}$	·038	
88	60	·027	

It will be seen there is greater friction on iron rails compared with steel rails, which is exactly what may have been expected. It should be clearly understood that friction can only take place between rough surfaces, and we know that a smooth surface of steel is, when planed or turned by the same tool, and at the same speed, smoother than an iron surface. Steel is denser than iron, and the atoms lie closer together; besides, steel is harder than iron, and so there is not the same facility for interlocking between steel and steel, as there is between iron and steel. In view of this circumstance, it is better both for stopping and starting to lay down iron rails in terminal or large central stations.

The diminution, as may be seen from the Table, in the co-efficient of friction arising from the time during which the surfaces were in contact, is not so marked in the case of the wheel sliding on the rail as in that of the wheel revolving against the brake-blocks.

The inference to be drawn from the results which have been obtained as to the low co-efficient of friction when a wheel skids is that where a rapid stop is required, the wheels should revolve, the force against them being less than what will actually skid them.

The Effect of the Application of the Brakes upon the Draw-bars of a Train.—The application of the brakes causes an immediate strain upon the draw-bars and couplings. If the brake is applied so as not to stop the rotation of the wheel, the strain is uniform, and the difference between the tractive force or strain on the draw-bar, before and after the application of the brake, is equal to the friction between the brake-blocks and the wheel added to the tractive force due to the speed. If the force of the brakes skid the wheels, the strain on the draw-bar drops at once, and if the force is suddenly withdrawn, it occasions a sudden strain on the draw-bar, because the adhesion between the rail and the wheel then comes into operation. In one experiment, out of a number of others, the friction between the brake-blocks and the wheel, which determined the point of skidding, was about 1,980 lbs., equivalent to ·19 of the weight on the wheels. At the moment when the wheels were beginning to rotate, after the brake was taken off, a strain was brought on the draw-bar of from 1,900 to 2,000 lbs. in excess of the average strain due to pulling the train when no brake was on.

Proportion which the Brake Force should bear to the Weight on the Wheels at Different Speeds.—It has been clearly proved from the experiments, which required no proving to practical railway men, that to skid a wheel tantamounts to bad braking, and therefore arises this question of proportion between force, weight, and speed. The higher the force applied to the wheels up to and not exceeding the skidding point, the greater is the stopping power. Now, it is obvious, this force must vary, both with the speed and the weight of a train. At present there are no means of letting drivers know on their engines what the weight of the train is, but the speed is in many instances known.

PROPORTION OF BRAKE PRESSURE TO WEIGHT.

Speed.		Approximate Ratio of Total pressure on Brake-blocks to Total Weight on Braked Wheels.			
Feet per second.	Miles per hour.	Co-efficient of Adhesion 0·30.	Co-efficient of Adhesion 0·25.	Co-efficient of Adhesion 0·20.	Co-efficient of Adhesion 0·15
11	7½	1·20	1·04	0·83	0·60
22	15	1·41	1·18	0·94	0·70
29	20	1·64	1·37	1·09	0·82
44	30	1·83	1·53	1·22	0·92
59	40	2·07	1·73	1·38	1·04
74	50	2·48	2·07	1·65	1·24
88	60	4·14	3·47	2·77	2·08

From the experiments, Captain Galton gives approximately the proportions which the pressure should bear to the weight upon the wheels to which the brakes are applied, with co-efficient of adhesion between the wheel and the rail, varying from ·30 to ·15 of the weight on the wheels. See the tabular statement, page 209.

It will be seen that when the adhesion equals ·30 of the weight, a pressure equal to 1·2 of the weight would skid the wheels at 7½ miles an hour, while a pressure equal to 4·14 times the weight would be required to do so at 60 miles an hour. Again, if the adhesion is only ·15, the force necessary to skid the wheel would be only ·60 of the weight at 7½ miles per hour, and 2·08 of the weight at 60 miles an hour.

Effect of the Time expended in bringing the Pressure to bear on the Wheels.—From a number of experiments made with the same object, it was found that the question of time was a most important factor. It was abundantly clear that the rapidity of the stop depended upon the quickness of the brake—while the speed is high—a second lost at 60 miles an hour means that the train ran—say into danger—88 feet without any effort being made to stop it; at 20 miles an hour it would only run 29 feet per second. For instance, a brake which reduces the speed from 60 miles an hour to 20 miles an hour in 6 seconds, has a great advantage as regards safety over a brake which would only reduce the speed from 60 miles an hour to 40 miles an hour in the same time.

III.—REPORT BY CAPTAIN GALTON ON BRAKE EXPERIMENTS, MADE AT GISBURN ON THE LANCASHIRE AND YORKSHIRE RAILWAY.

THE trains consisted of:—

1st. One train fitted with the Eames Brake.
2nd. Two trains fitted with the Westinghouse Brake.
3rd. One train fitted with the Sanders Brake.
4th. One train fitted with the Fay and Newall Brake.

The trains fitted with the Eames and Sanders Brakes, and one Westinghouse train, had been working on the Lancashire and Yorkshire Railway, and one Westinghouse train had been working on the Great Northern Railway.

The relative weights are shown in the following Table:—

Description of Brake.	Vehicles.	Weights of Vehicles.			Braked Weights.		
		Tons	Cwt.	Qrs.	Tons	Cwt.	Qrs.
EAMES TRAIN .	Engine and Tender	52	7	0	40	15	0
	Train	72	18	3	72	18	3
	Experimental Van .	9	12	0	....		
	Total . .	134	17	3	113	13	3
SANDERS TRAIN	Engine	40	0	0	31	15	0
	Train	72	2	2	72	2	2
	Experimental Van .	9	12	0	....		
	Total . .	121	14	2	103	17	2
WESTINGHOUSE (GREAT NORTHERN TRAIN)	Engine and Tender	57	10	1	49	0	3
	Train	75	13	1	69	0	2
	Experimental Van .	9	12	0	....		
	Total . .	142	15	2	118	0	5

Description of Brake.	Vehicles.	Weights of Vehicles.			Braked Weights.		
		Tons	Cwt.	Qrs.	Tons	Cwt.	Qrs.
WESTINGHOUSE (LANCASHIRE AND YORKSHIRE TRAIN)	Engine	44	0	0	27	0	0
	Train	88	5	0	59	17	1
	Experimental Van .	9	12	0	....		
	Total . .	141	17	0	86	17	1
FAY TRAIN . . .	Engine and Tender	53	6	0	42	5	0
	Train	71	14	1	71	14	1
	Experimental Van .	9	12	0	....		
	Total . .	134	12	1	113	19	1

The following Table, A, shows the results obtained: Column No. 9 shows the various results worked out to 50 miles per hour on a level, and with the allowance made for the different percentages of the braked to the unbraked portion of the train; allowance also being made for the rotating momentum of the unbraked wheels in the train (but not those on the engine) which is estimated as an additional unbraked weight of 8 cwt. for each pair of wheels,—an estimate a little under the true amount.

The percentages thus obtained are as follows:—

BRAKE.	Percentage Braked with Engine.	Percentage Braked when Slipped.	Influence of Momentum of Unbraked Wheels in percentage of whole weight of Train with Engine.	Same when Slipped.	Corrected percentage of Braked weight of the Train with Engine.	Same without Engine when Slipped.	Number of Unbraked Axles not including Engine.
EAMES	84·2	88·9	0·5	0·81	83·7	88·1	2
SANDERS	85·3	88·2	0·55	0·82	84·8	87·4	2
WESTINGHOUSE G.N.	82·8	80·1	0·94	1·6	81·9	78·5	4
WESTINGHOUSE L. & Y.	61·2	62·3	2·5	3·7	52·7	58·6	9
FAY	84·6 53·2	..	0·5	..	52·7	..	2

From the formula $\frac{P v^2}{2 g} = F \times d$, in which P is the weight of the train, v the speed in feet per second, F the average retarding force, d the distance in which the train is stopped; the retardation in percentage of the weight of the train is equal to the constant 3·34 multiplied by the square of the speed in miles per hour, divided by the distance of the stop in feet.

The influence of a gradient in percentage of retardation is equal to the fall or rise per hundred units of distance. Thus the gradient of $\frac{1}{100}$ gives a retardation or acceleration of 1 per cent.

The percentages of retardation were corrected in the inverse ratio of the braked weight of the train.

The Eames train was taken as a standard. The percentage of the braked weight of that train was 83·7 per cent. of the total weight of the train with the engine, and 88·1 of the weight of the detached portion of the train during the slip stops.

The equivalent distance at 50 miles per hour on a level is obtained by dividing the constant (8353) by the corrected percentage of retardation.

TABLE A.—RESULTS OF CAPTAIN GALTON'S EXPERIMENTS WITH CONTINUOUS BRAKES, ON THE LANCASHIRE AND YORKSHIRE RAILWAY, 1880.

$$x = 3{\cdot}34\ \frac{v^2}{d}$$

$$D = \frac{8353}{x}$$

FIRST DAY.

x = Percentage of retardation.
v = Speed in miles per hour.
d = Distance of stop.
D = Equivalent distance at 50 miles per hour

1	2	3	4	5	6	7	8	9	10	11	12
No. of Experiment.	Description of Brake.	Percentage of Train Braked.	Speed in miles per hour.	Distance run in feet after application of Brake.	Gradients.	Percentage of retardation.	Corrected percentage for non-braked wheels and gradients.	Equivalent distance in feet for 50 miles an hour on a level.	Kind of Stop.	State of Rails.	Remarks.
1	WESTINGHOUSE	81·9	41·5	485	$\frac{1}{100}$ down	11·85	13·14	635	Quick stop	Moist	Great Northern Train.
2	„ „	81·9	61	1,185	Level	10·46	10·71	779	„	„	„ „
3	„ „	58·7	67	2,055	$\frac{1}{100}$ down	7·29	11·82	707	„	„	Lancashire and Yorkshire Train.
4	EAMES	83·7	46	1,465	Level	4·82	4·82	1733	„	„	Large Ejector disconnected, and only opened towards end of stop.
5	„	88·1	44·5	705	$\frac{1}{100}$ down	9·35	10·35	807	Slip stop	„	
6	„	83·7	64·5	1,490	Level	9·31	9·31	897	From van	„	
7	SANDERS	84·8	49	1,160	$\frac{1}{100}$ down	6·91	7·80	1070	Quick stop	„	
8	„	84·8	59	1,620	Level	7·14	7·04	1186	From van	„	

SECOND DAY.

1	2	3	4	5	6	7	8	9	10	11	12
9	WESTINGHOUSE	81·9	66	1,380	Level	10·54	10·77	775	Quick stop	Moderate dry	Great Northern Train.
10	„ „	81·9	46	680	$\frac{1}{100}$ down	10·39	11·64	718	„	„	„ „
11	EAMES	83·7	61	1,205	Level	10·31	10·31	810	„	„ wet	
12	„	83·7	46	705	$\frac{1}{100}$ down	10·02	11·02	757	„	Wet	
13	„	88·1	59·5	995	Level	11·89	11·89	702	Slip stop	„	
14	„	88·1	35	455	„	8·99	8·99	928	From van (steam on)	„	
15	SANDERS	84·8	45	705	$\frac{1}{100}$ down	9·59	10·45	799	Quick stop	Average	
16	„	87·4	48	675	Level	11·39	11·49	727	Slip „	„	
17	„	84·8	50	895	„	9·36	9·23	905	Quick „	„	
18	„	84·8	39	625	„	8·12	8 01	1042	From van	Wet	
19	„	87·4	45	625	„	10·82	10·90	766	Slip stop	Average	

THIRD DAY.

20	WESTINGHOUSE	78·5	45	410	$\frac{1}{100}$ down	16·37	19·49	428	Slip stop ..	Very dry	Great Northern Train.
21	„ „	78·5	44·5	430	$\frac{1}{100}$ „	15·38	18·38	454	„ ..	„ „	„ „
22	„ „	58·7	59·5	1,575	Level ..	7·50	10.69	781	Quick stop	„ „	Lancashire and Yorkshire Train.
23	„ „	58·7	55	1,650	„ ..	6·12	8·73	956	From van ..	„ „	Lancashire and Yorkshire Train, steam on.
24	„ „	58·7	46	900	$\frac{1}{100}$ down	7·85	12·62	661	Quick stop	„ „	Lancashire and Yorkshire Train.
25	„ „	58·6	52	1,235	$\frac{1}{100}$ „	7·31	12·49	668	Slip stop ..	„ „	Accidental slip, engine broke away.
26	„ „	58·7	46	1,175	$\frac{1}{100}$ „	6·01	10·00	835	From van ..	„ „	Steam on.
27	EAMES	83·7	43·5	600	$\frac{1}{100}$ „	10·53	11·53	724	Automatic alone	„ „	Non-Automatic Brake on engine used.
28	„	83·7	45·5	575	$\frac{1}{100}$ „	12·02	13·02	641	Quick stop	„ „	
29	„	83·7	57	1,200	$\frac{1}{100}$ „	9·04	10·04	831	„	„ „	
30	„	83·7	53·5	1,050	Level ..	9·10	9·10	918	From van ..	„ „	Steam partly on.
31	SANDERS	84·8	46	730	$\frac{1}{100}$ down	9·68	10·54	792	Quick stop	„ „	
32	„	87·4	51	715	Level ..	12·14	12·23	683	Slip stop ..	„ „	
33	FAY'S	84·1	45	740	$\frac{1}{100}$ down	9·13	10·08	828	Quick stop	„ „	
34	„	52·7	59·5	1,810	Level ..	6·52	10·36	806	„	„ „	Steam on.'

AVERAGES OF ABOVE STOPS (in feet) from Column 9.

Description of Brake.	Stops by Driver.	Stops from Van.	Slip Stops.	Remarks.
WESTINGHOUSE	727	Not tried.	441	Great Northern Train.
„	716	895	668	Lancashire and Yorkshire Train.
EAMES	752	914	754	Not including experiment No. 4.
SANDERS	891	1,114	722	

The differences in the brake power on the various engines are shown by the following comparison between quick stops with the engine, and the stops of the detached carriages when the trains were slipped.

The stops averaged at 50 miles per hour are as follows:—

	Slip Stops without Engine.	Quick Stops with Engine.
EAMES	754 feet.	752 feet.
SANDERS	722 ,,	891 ,,
WESTINGHOUSE (GREAT NORTHERN TRAIN) . .	441 ,,	727 ,,
WESTINGHOUSE. (LANCASHIRE AND YORKSHIRE TRAIN). Train accidentally broken in two by failure of slip coupling after the brake was applied from engine.	668 ,,	716 ,,

The slip stops, as compared with the other stops, indicated that, in the case of the Eames train, the engine was quite as well braked as the train; whilst with the Sanders and the Lancashire and Yorkshire Westinghouse train, there was not as much power on the engines as on the trains. In the case of the Great Northern train, there was apparently a great deficiency in the brake power applied to the engine and tender, as shown by the great difference between the ordinary stops and the slip stops.

IV.—TRIALS ON THE NORTH BRITISH RAILWAY.

IN December, 1876, a series of trials were carried out between the automatic and the vacuum brakes. The vacuum-brake, it may be remarked, is worked in Europe by an independent company, although in the United

RAILWAY.

7 .A.	12 S.V.	12 W.A.	11 S.V.	10 W.A.	13 W.A.	14 W.A.
0	**54**	**54**	**55**	**55**	**56**	**54**
·75	28	21	28	21	26	26·25
77	**1310**	**952**	**1375**	**910**	**1172**	**1158**
·	75	..	75	..	..	..
·	72·6	..	66·2	..	..	..
875	**16840**	**16184**	**17450**	**16789**	**17405**	**16184**
·85	12·861	17·00	12·682	18·44	14·9	13·97
9·3	166·27	226·9	164·34	247·3	199·1	187·3
2·0	196·71	262·3	200·35	267·2	219·7	209·8
0·8	**179·63**	**247·2**	**177·54**	**269·5**	**215·9**	**204·2**
6·0	214·07	285·8	218·03	290·8	239·4	228·7
4·1	204·45	288·3	201·41	314·3	251·8	238·2
5·2	243·56	333·3	248·11	339·1	279·2	266·7
·5	·46	1·39	·45	·226	1·8	·091

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States it is the property of the Westinghouse Company.

GENERAL PARTICULARS OF ENGINE FOR EACH TRAIN.

	ft.	in.
Number of coupled wheels	4	
Diameter of wheels	6	6
Distance between coupled wheels	7	7
Distance from centre of driving wheels to centre of bogie-pin	9	8⅜
Number of wheels in bogie	4	
Diameter ,, ,,	2	9
	tons	cwt.
Weight on driving wheels	24	9
,, bogie	13	11
Total	38	0
Position of cylinders	Inside	
	in.	
Diameter ,,	17	
Stroke ,,	24	
Heating Surface :		
	sq. ft.	
208 tubes 1⅝ in. in diameter	894	
Firebox	87	
Total	981	
Grate area	15.75	

LEADING PARTICULARS OF TRAIN FITTED WITH SMITH VACUUM-BRAKE.

Weight of Train.

Engine.	Tender.	Carriages	Vans.	Passengers.	Total.
tons. 38	tons cwt. 21 10	tons cwt. 75 8	tons cwt. 36 2	tons. 2	tons. 173

Number of Wheels.

Engine.	Tender.	Carriages	Vans.	Passengers.	Total.
8	6	32	16	..	62

Number of Brake-Blocks.

Engine.	Tender.	Carriages	Vans.	Passengers.	Total.
4	6	32	12	..	54

Number of iron blocks . .	42		tons cwt.
„ wooden blocks .	12	Weight of engine unbraked	13 11
		„ train „	9 14
		Total weight unbraked	23 5

Proportion of weight braked to unbraked, 149.75 : 23.25; or portion braked = 86.55 per cent. of total weight of train.

LEADING PARTICULARS OF TRAIN FITTED WITH WESTINGHOUSE AUTOMATIC-BRAKE.

Weight of Train.

Engine.	Tender.	Carriages.	Vans.	Passengers.	Total.
tons. 38	tons cwt. 21 10	tons cwt. 85 2	tons cwt. 19 18	tons. 2	tons cwt. 166 10

Number of Wheels.

8	6	36	8	..	58

Number of Brake-Blocks.

4	6	36	4	..	50

All brake blocks of iron.		tons cwt.
	Weight of engine unbraked	13 11
	„ train „	9 14
	Total	23 5

Proportion of weight braked to unbraked, 143.25 : 23.25; or portion braked = 86.02 per cent. of total weight of train.

NOTES TO TABLE OF CONTINUOUS-BRAKE TRIALS.

No. 2. Smith's Vacuum-Brake.

	lbs.
Boiler pressure on application of ejector . . .	138
Boiler pressure when ejector was shut off	138
Vacuum .	17 in.

No. 3. Westinghouse Automatic-Brake.

	lbs.
Pressure in air reservoir .	85

No. 5. Smith's Vacuum-Brake.

	lbs.
Boiler pressure on application of ejector	144
Boiler pressure when ejector was shut off	143
Vacuum	18 in.

No. 5. Westinghouse Automatic-Brake.

	lbs.
Pressure in air reservoir	85

No. 6. Smith's Vacuum-Brake.

	lbs.
Boiler pressure on application of ejector	144
Boiler pressure when ejector was shut off	144
Vacuum	18 in.

No. 4. Westinghouse Automatic-Brake.

	lbs.
Pressure in air reservoir	90

No. 14. Smith's Vacuum-Brake.

	lbs.
Boiler pressure on application of ejector	144
Boiler pressure when ejector was shut off	148
Vacuum	19¼ in.

No. 4. Westinghouse Automatic-Brake.

	lbs.
Pressure in air reservoir	90

No. 15. Smith's Vacuum-Brake.

	lbs.
Boiler pressure on application of ejector	140
Boiler pressure when ejector was shut off	137
Vacuum	17 in.

No. 6. Westinghouse Automatic-Brake.

	lbs.
Pressure in air reservoir	90

No. 7. Smith's Vacuum-Brake.

	lbs.
Boiler pressure on application of ejector	124
Boiler pressure when ejector was shut off	122
Vacuum	19½ in.

No. 6. Westinghouse Automatic-Brake.

	lbs.
Pressure in air reservoir	90

No. 9. Smith's Vacuum-Brake.

	lbs.
Boiler pressure on application of ejector	144
Boiler pressure when ejector was shut off	148
Vacuum	19¾ in.

No. 7. Westinghouse Automatic-Brake.

	lbs.
Pressure in air reservoir	101

No. 12. *Smith's Vacuum-Brake.*

	lbs.
Boiler pressure on application of ejector . . .	144
Boiler pressure when ejector was shut off	142
Vacuum .	18 in.

No. 11. *Smith's Vacuum-Brake.*

	lbs.
Boiler pressure on application of ejector . . .	108
Boiler pressure when ejector was shut off	108
Vacuum .	20 in.

No. 13. *Westinghouse Automatic-Brake.*

	lbs.
Pressure in air reservoir .	95

Note.—This stop was made from the Experimental Van against engine working with usual degree of expansion.

No. 12. *Westinghouse Automatic-Brake.*

	lbs.
Pressure in air reservoir .	97½

No. 10. *Westinghouse Automatic-Brake.*

	lbs.
Pressure in air reservoir .	94

No. 14. *Westinghouse Automatic-Brake.*

	lbs.
Pressure in air reservoir .	90

Note.—This stop was made from the Experimental Van against engine working under full steam.

V.—REPORT BY MR. T. E. HARRISON, TO THE NORTH-EASTERN RAILWAY COMPANY, ON THE WESTINGHOUSE AUTOMATIC-BRAKE.

To the Directors of the North-Eastern Railway Company.

Newcastle-on-Tyne, 24*th April*, 1879.

Gentlemen,—

In the early part of 1878, I explained to you my views as to the different continuous-brakes then in use, and recommended you to adopt the Westinghouse Automatic Pressure Brake as the brake of your system, a recommendation which you afterwards adopted, subject to the necessary user of Smith's Vacuum-Brake for the through Scotch traffic, run in connection with the Great Northern Railway, so long as that Company continued to use that system.

Since then I have continued to give constant attention to the subject, and have had immediate reports made to me of every incident that has occurred in the practical use of this brake, with a view to see what weak points there were in it, and to consider the remedy to be adopted.

I may state at once that these investigations have confirmed more strongly than ever the opinion I then gave you in favour of the Westinghouse Automatic Brake, for though in its principle no alterations have been made, or found necessary, many small and simple modifications have been made in details, which have greatly added to the uniformity and certainty of its action.

I did not, at the time you decided on adopting this brake, press on you its immediate application to the whole of your trains, but only to some of your fast trains, to which it was of importance, as I was anxious to watch all defects, and have the necessary remedy supplied; and I may state that as they have from time to time been pointed out to Mr. Westinghouse, he has in every case, if he had not anticipated the suggestions, been able without difficulty to supply a complete remedy.

The Westinghouse Automatic Brake continues still in use in America, and has proved itself to be well suited to that particular traffic, and has required little or no modification, but when applied to railways in England, the circumstances were so different that many alterations were necessary in the details.

Looking at the continuous-brake system as a novel invention, whether vacuum or pressure, it must be obvious to any one acquainted with such inventions, that perfection could not be expected at once, and the Westinghouse automatic system has been no exception to this rule, and I purpose briefly to call your attention to some of the most important modifications which have been introduced by Mr. Westinghouse since the brake trials at Newark in 1875, some of these being of a recent date.

Triple-Valve.—As the most important, I will particularly draw your attention to the "triple-valve," which has been made a regular bugbear by the opponents of the system, and has been called complicated, delicate, and liable to get out of order, &c. The original "triple-valve" used at the "Newark experiments," a drawing of which I have now before me, has three distinct valves, and hence its name "triple-valve," and it might, in its original construction, have to some extent deserved the term complicated, but the valve, as altered shortly after the Newark trials, and as now constructed, differs so entirely from the original valve, that although I think it desirable to continue the term "triple-valve," its present construction would not have suggested or justified that term; it is, in fact, as simple a piece of mechanism as well can be imagined, certain in its action, of durable materials, easily accessible to an ordinary workman for examination or cleaning, and there is nothing about it that can justify the term complication; on the contrary, it is a model of ingenuity and simplicity.

Leakage-Valve.—In order to prevent the possibility of the brakes going on by a leakage from the reservoir on the carriage to the brake-cylinder, Mr. Westinghouse introduced a "leakage-valve" between the triple-valve and the brake-cylinder, but this has since been done away with by the simple expedient of cutting a short groove at the inner end of the brake-cylinder, so as to allow an escape of air under the piston when in a state of rest.

Hose-Couplings.—A great improvement has been made in the couplings of the carriages. There used to be a cock at each end of each carriage, and before removing a carriage from a train it was necessary to turn four cocks to completely shut off communication, and cases have occurred where, from carelessness, a cock has not been reopened, and thus the air-pressure was shut off from the hinder portion of the train. To meet this, Mr. Westinghouse has introduced valves into the couplings, and the mere act of disconnecting closes the valves and retains the air, and the act of reuniting the couplings opens the valves and makes again a free passage for the air through the main pipes.

By this arrangement two cocks on each carriage are dispensed with, and the leakage-valve being superseded as above-mentioned, there only now remain on each carriage two ¼-inch cocks of the simplest construction, one to be used when it may be necessary to shut off the brake-action on any particular carriage, the other in the same case to let the air out of the brake-cylinder.

The Driver's Brake-Valve.—The driver's brake-valve gives the engineman the means of applying the brake with any degree of power, and retains in the main reservoir a pressure equal to 20 pounds per square inch above the ordinary pressure in the brake pipes, and this extra pressure is at the command of the driver at any time, and enables him more rapidly to release the brake-blocks and re-charge the main pipes and the carriage-reservoirs.

Automatic Regulation for Donkey-Pump.—Another important point is the introduction, on the donkey-engine, of an automatic regulator for the donkey-pump, which has a connection with the main pipes, and is so adjusted that whenever the pressure in the main pipes falls below a fixed standard, which may be varied to any extent to suit the nature and circumstances of the train, the donkey-engine is set to work, and this will ensure a sufficiently constant uniformity of pressure in the main pipes, a point of very great importance.

There are other minor improvements, such as welding all the reservoirs instead of riveting them, but they are not of sufficient importance to demand separate notice.

It may here be remarked that there is no difficulty in arranging an automatic pressure-brake to act without valves, but all such brakes must of necessity have one inherent and fatal disadvantage of slow action; and when rapidity of application of the brakes is measured by one, two, or three seconds in time, representing in some cases 30 to 100 yards of difference in stopping distance, the objection is fatal.

I have had carriages so fitted up, and tried them mixed up with carriages fitted with the Westinghouse Brake, and the difference in time in applying and releasing the brakes is so marked that they could not be worked together, though alone they worked quite well.

I have, therefore, arrived at the conclusion that no pressure-brake, which has not a valve which will produce the same effect as the Westinghouse triple-valve, can be used as a general brake, and it will be found very difficult to find anything more simple and reliable in its action than that valve as now constructed.

It is hardly necessary for me to repeat to you what I have frequently said, viz. that I entirely agree with the Board of Trade in the conditions they have laid down as being necessary to constitute a good continuous brake, all of which the Westinghouse Brake complies with.

I have heard it constantly stated that the vacuum-brake is cheaper than the Westinghouse Brake, both in first cost and to maintain. I have lately had the brake-gear of a similar carriage fitted with the vacuum and Westinghouse Brakes as now in use on your railway, taken to pieces and accurately weighed, and also a complete set of each made in the shops, and taking into account the amount paid in each case to the respective patentees for what they supply, the first cost is decidedly in favour of the Westinghouse, and the weight of wrought and cast-iron necessary for the brake-gear is 10 cwt. per carriage heavier in the case of the vacuum than in the Westinghouse.

Should it be decided to adopt a vacuum automatic Brake there must be some considerable additions both to the first cost and maintenance.

As to the annual cost of maintenance, there being no strictly so-called perishable material in the Westinghouse Brake, except the couplings which are common to both systems, whereas in the vacuum-brake the sacks must always be liable to great wear and tear from their perishable nature, and the fact of the larger amount of brake-gear in the vacuum-brake to be maintained, I have no doubt that the Westinghouse Brake will be more cheaply maintained than the vacuum, and all the information I have got confirms this view.

I have thought it desirable to lay this report before you, having taken the responsibility of recommending you to adopt the Westinghouse Automatic Brake as the brake of your system, and every day's experience further confirms my views, and I am confident that there is no brake which will beat it in stopping power, in economy of first cost and maintenance, or in certainty of action.

I remain, &c.,
(Signed) THOS. E. HARRISON.

The Directors of the
North-Eastern Railway Company.

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